OAK REGENERATION IN OAK AND PINE STANDS ON DRY-MESIC SITES: 19-YEAR RESULTS




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BACKGROUND:

Began in the late 1980's in conversation with Michigan DNR personnel (Bill Botti, Bill Mahalak, Bill Tarr, and Don Hennig)

- **Based on observations of oaks invading understories of pine stands and vice versa**

- **Keen interest in utilizing existing pine plantations in particular to secure oak regeneration**

BACKGROUND *continued*:

Led to a study of "Interactions in the regeneration of oaks and pines in northern Lower Michigan" in 1989

- Funded by Michigan DNR, FS North Central Forest Experiment Station, and USDA through Michigan Technological University

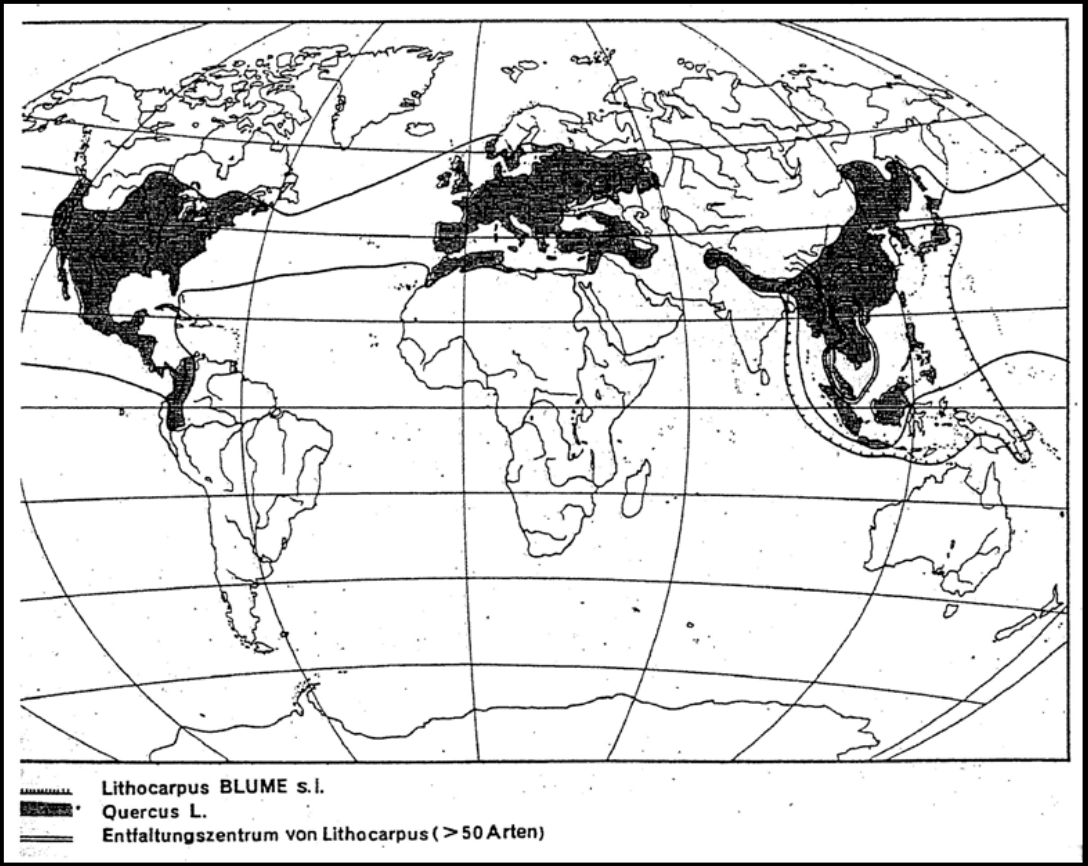
BACKGROUND *continued*:

Phase I: Literature Review (Sharik and Sarnecki 1989)

- **Oaks and pines have similar distributions geographically and occupy similar habitats and niches**

BACKGROUND *continued*:

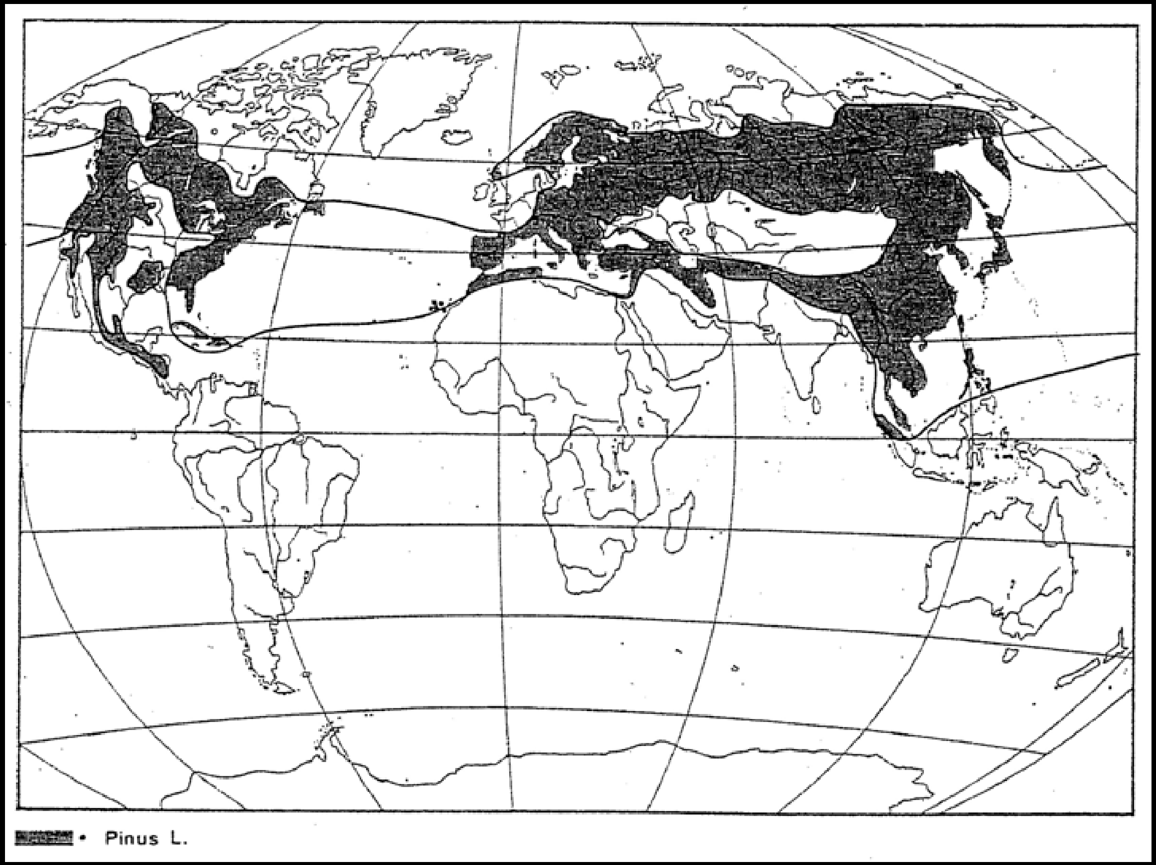
GLOBAL DISTRIBUTION OF OAK SPECIES



Muesel et al. 1965

BACKGROUND *continued*:

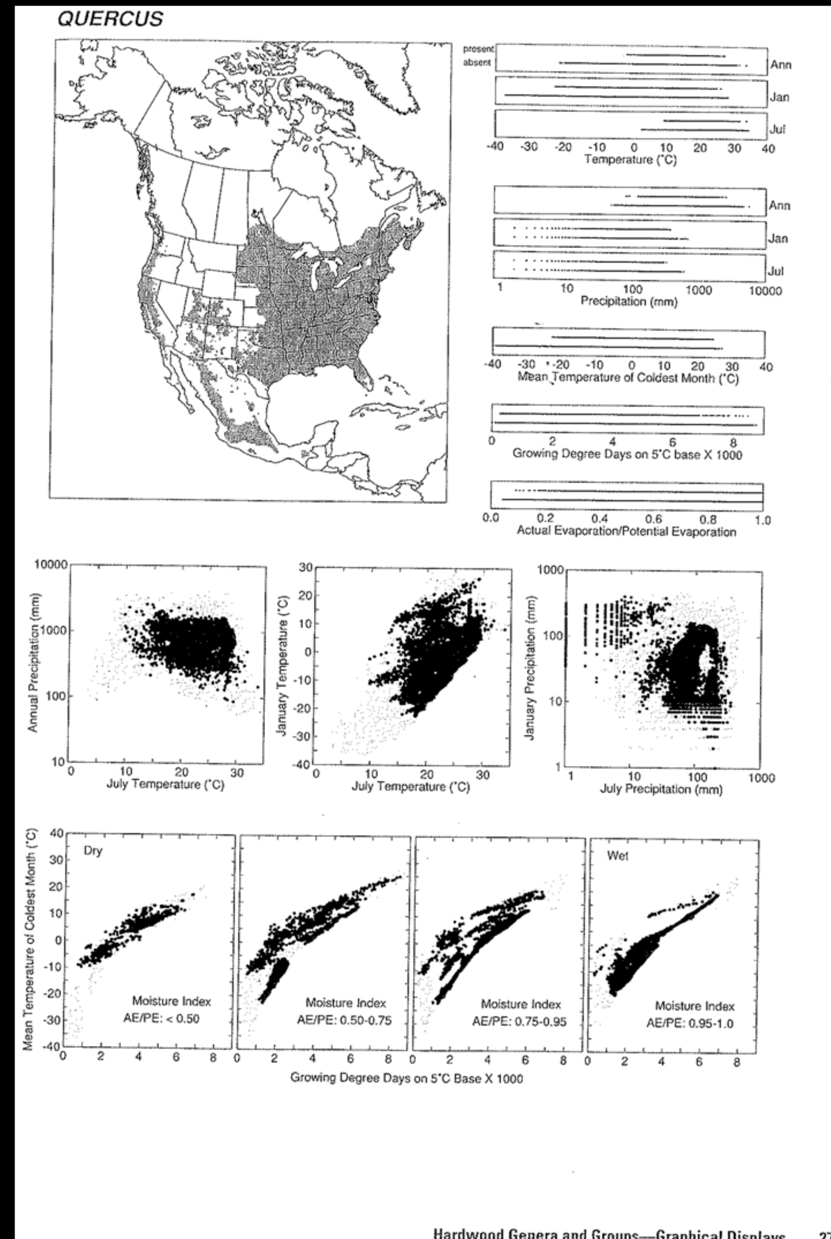
GLOBAL DISTRIBUTION OF PINE SPECIES



Muesel et al. 1965

BACKGROUND *continued*:

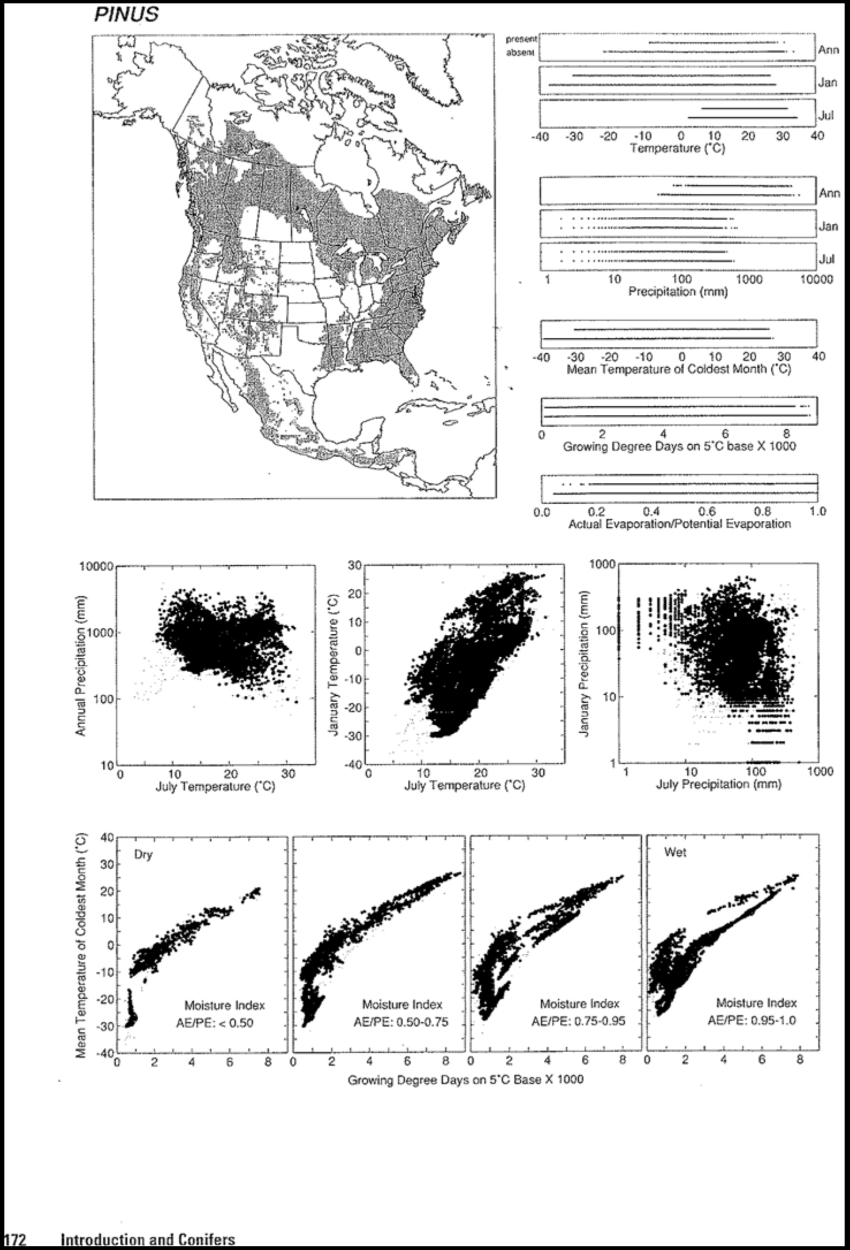
DISTRIBUTION OF OAK SPECIES IN NORTH AMERICA



Thompson et al. 1999

BACKGROUND *continued*:

DISTRIBUTION OF PINE SPECIES IN NORTH AMERICA



Thompson et al. 1999

BACKGROUND *continued*:

- Published observations of reciprocal replacement of oaks and pines in North America go back at least as far as Thoreau (1860)

"….While the wind is conveying the seeds of pines into hard woods, the squirrels and other animals are conveying the seeds of Oaks and walnuts into the pine woods."

BACKGROUND *continued*:

Ultimate Factors

- Dispersal agents
- Forest floor conditions
- Available moisture
- Available nutrients
- Light quantity and quality
- Late spring frost
- Ice and snow loads
- Plant exudates (allelopathy)
- Fire (intensity and frequency)
- Diseases and insects
- Herbivores
- Mycorrhizae
- Other plants
- Tolerance levels of target species

Proximal/Surrogate Factors

- Canopy quality
- Canopy quantity
- Understory quality and quantity
- Ecological land type

BACKGROUND *continued*:

Phase IIA: DNR Stand Inventory (Sharik and Sarnecki 1989)

- **Six counties comprising the Highlands District in northern Lower Michigan: Crawford, Kalkaska, Missaukee, Ogemaw, Oscoda, and Roscommon**

BACKGROUND *continued*:

LOWER MICHIGAN LANDSCAPE ECOSYSTEMS

Albert et al. 1986

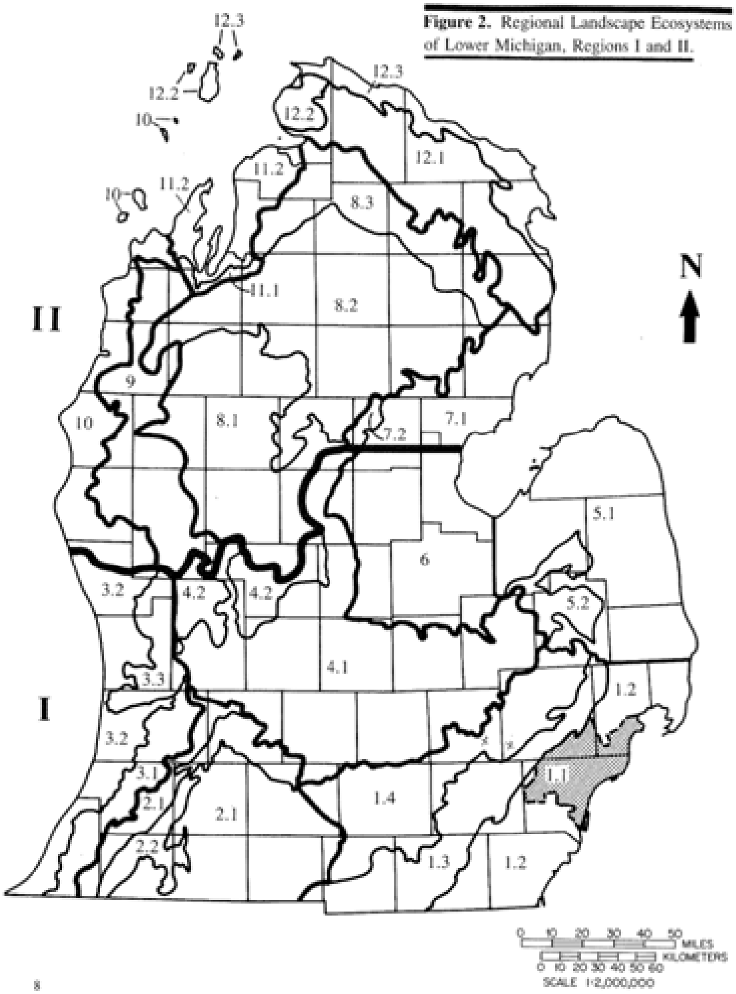


Figure 2. Regional Landscape Ecosystems of Lower Michigan, Regions I and II.

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Table 1. Regional Landscape Ecosystems of Lower Michigan, Regions I and II.

No.	District	Subdistrict	Site Condition	Area Sq Mi (km^2)
Region I: Southern Lower Michigan				
1.1	Washtenaw	Detroit	Heat island	
1.2		Maumee	Lake plain	2300 (5960)
1.3		Ann Arbor	Fine and medium-textured moraine	1635 (4235)
✓ 1.4		Jackson	Interlobate; coarse-textured end moraine, outwash, and ice-contact typography	2060 (5335)
2.1	Kalamazoo	Battle Creek	Outwash and ground moraine	2770 (7175)
2.2		Cassopolis	Coarse-textured and end moraine and ice-contact terrain	720 (1865)
3.1	Allegan	Berrien Springs	End and ground moraine	760 (1970)
3.2		Benton Harbor	Lake plain	1355 (3510)
3.3		Jamestown	Fine-textured end and ground moraine	490 (1270)
4.1	Ionia	Lansing	Medium-textured ground moraine	4810 (12460)
4.2		Greenville	Coarse-textured end and ground moraine	760 (1970)
5.1	Huron	Sandusky	Lake plain	3210 (8319)
5.2		Lum	Medium and coarse-textured end-moraine ridges and outwash	480 (1245)
6.1	Saginaw		Lake plain	2390 (6190)
Region II: Northern Lower Michigan				
7.1	Arenac	Standish	Lake plain	1295 (3355)
7.2		Wiggins Lake	Fine-textured end and ground moraine	110 (285)
8.1	Highplains	Cadillac	Coarse-textured end moraine	2860 (7405)
8.2		Grayling	Outwash	4085 (10580)
8.3		Vanderbilt	Steep end- and ground-moraine ridges	1505 (3900)
9	Newaygo		Outwash	1920 (4975)
10	Manistee		End moraine and sand lake plain	1480 (3835)
11.1	Leelanau	Williamsburg	Coarse-textured end-moraine ridges	100 (260)
11.2		Traverse City	Coarse-textured drumlin fields on ground moraine	750 (1940)
12.1	Presque Isle	Onaway	Drumlin fields on coarse-textured ground moraine	1845 (4780)
12.2		Stutsmanville	Steep and ridges	270 (700)
12.3		Cheboygan	Lake plain	835 (2165)

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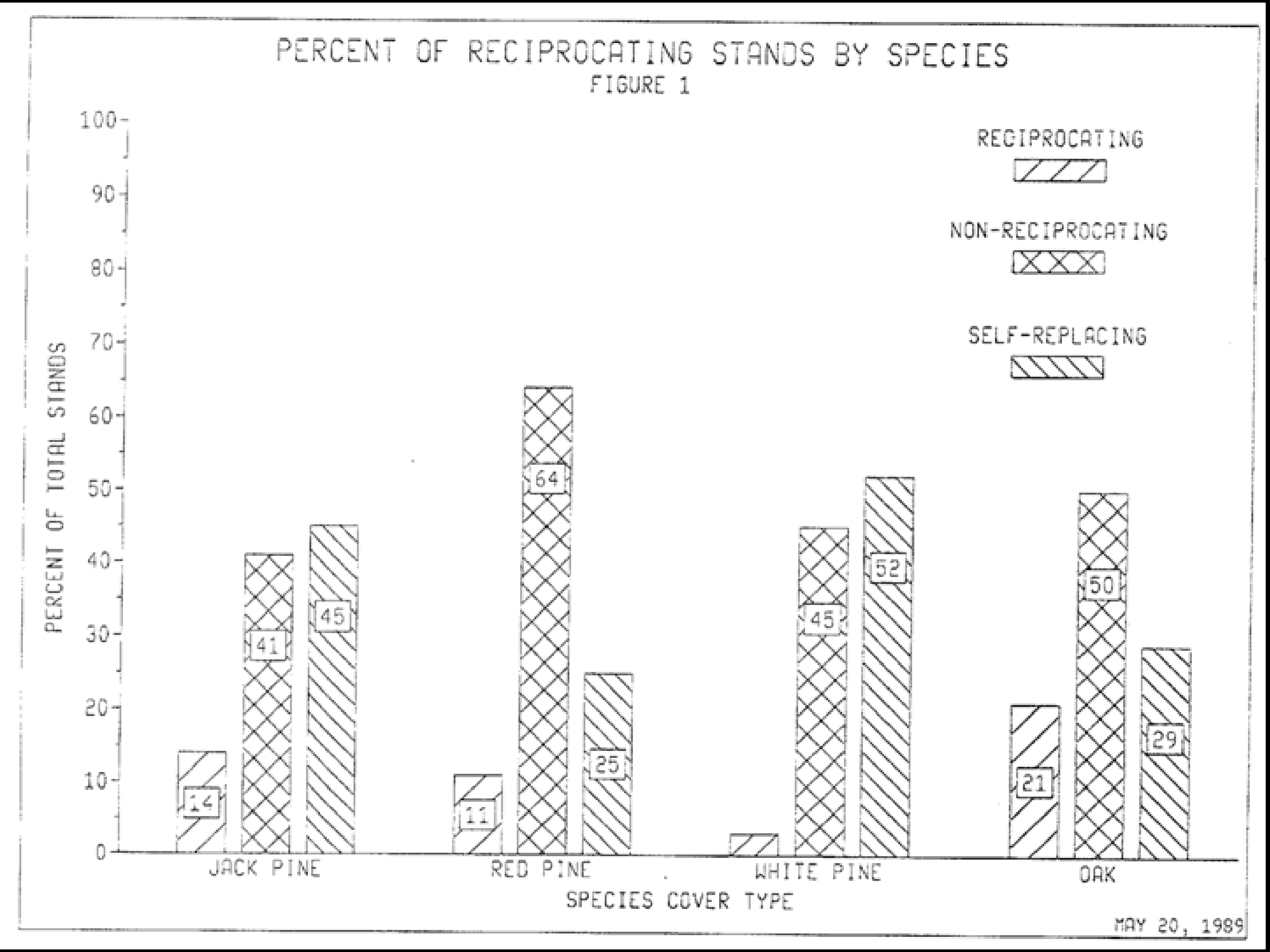
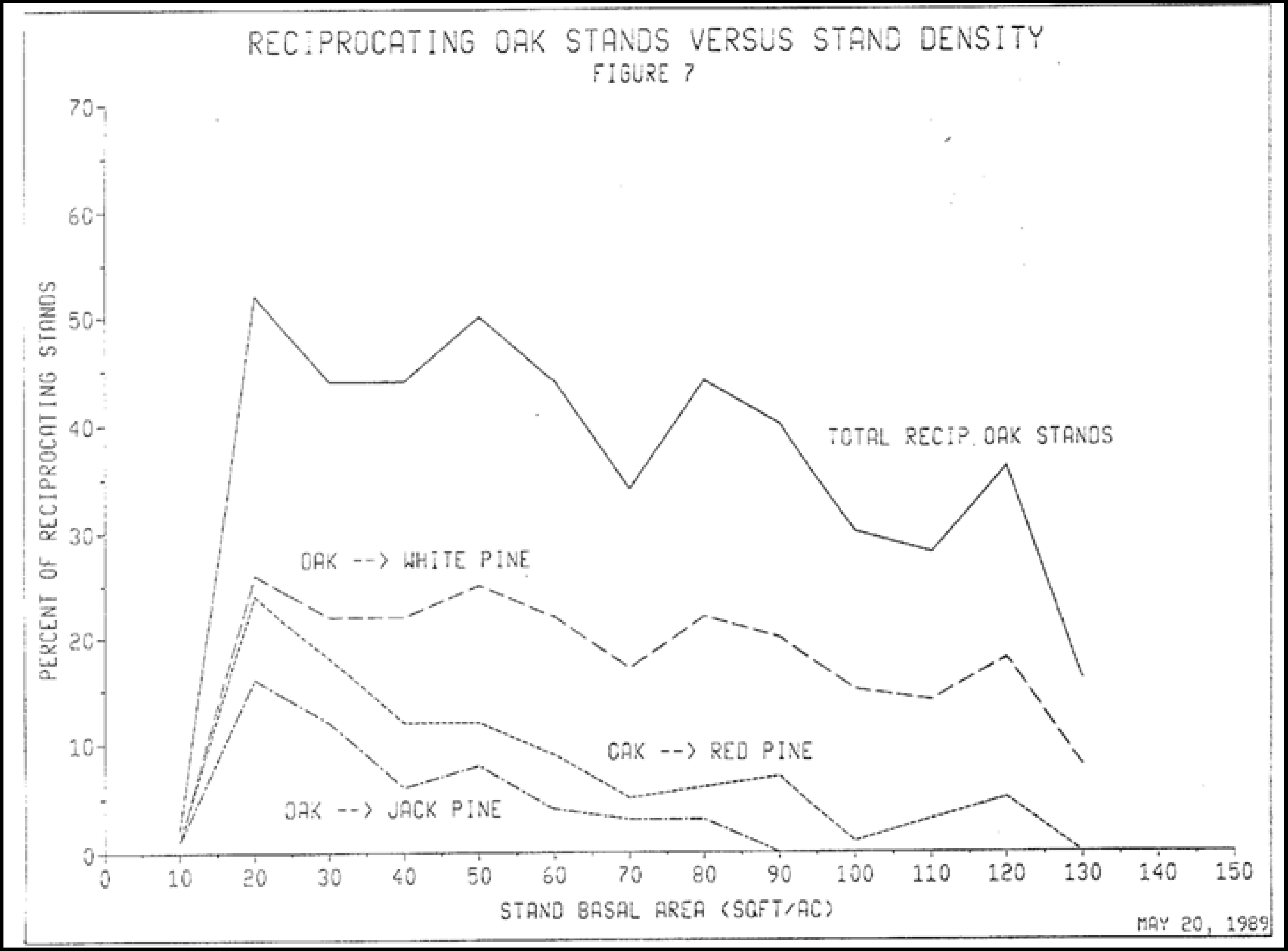
BACKGROUND *continued*:

- 1979-1989 Inventory of all stands containing oak and/or pine (n = 5,955)

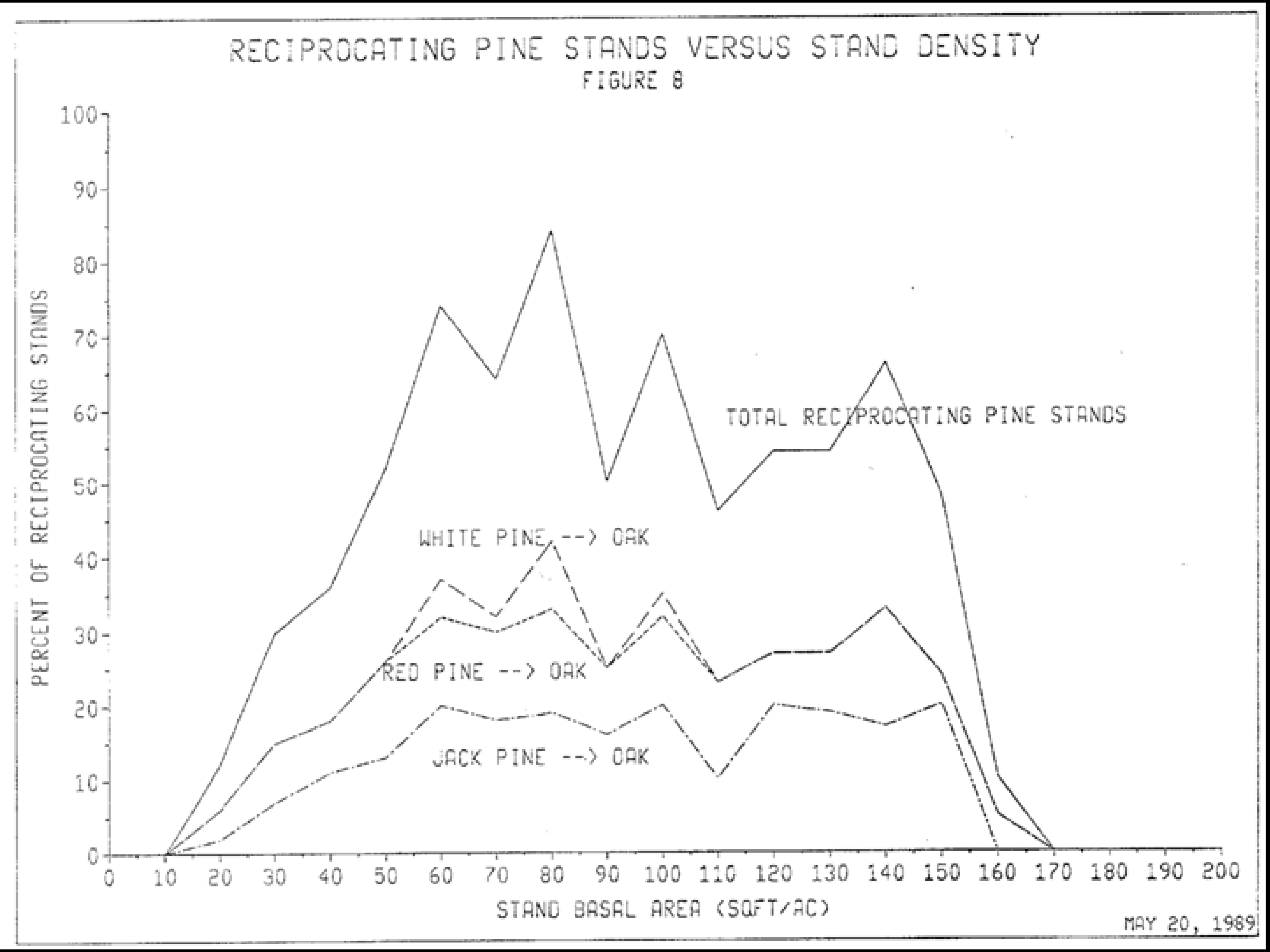
BACKGROUND *continued*:



BACKGROUND *continued*:



BACKGROUND *continued*:



BACKGROUND *continued*:

- White pine was maximally replaced by oaks on intermediate quality sites (SI_{50} = 60-69), while red pine and jack pine more so on sites of slightly lower quality (SI_{50} = 50-59)

- Overall trends were less clear than for overstory basal area

BACKGROUND *continued*:

- Limitations

1) Data in a format difficult to interpret ecologically

2) Data collection highly variable in format

3) No efficient method of identifying stands established as plantations or manipulated (thinning, etc.)

4) Nothing experimentally controlled

BACKGROUND *continued*:

Phase IIb: Preliminary reconnaissance and sampling of potential study sites (Sharik and Sarnecki 1989)

- **Visited 50 reciprocating stands and sampled in 23**

- **Subset of stands selected for controlled experiments**

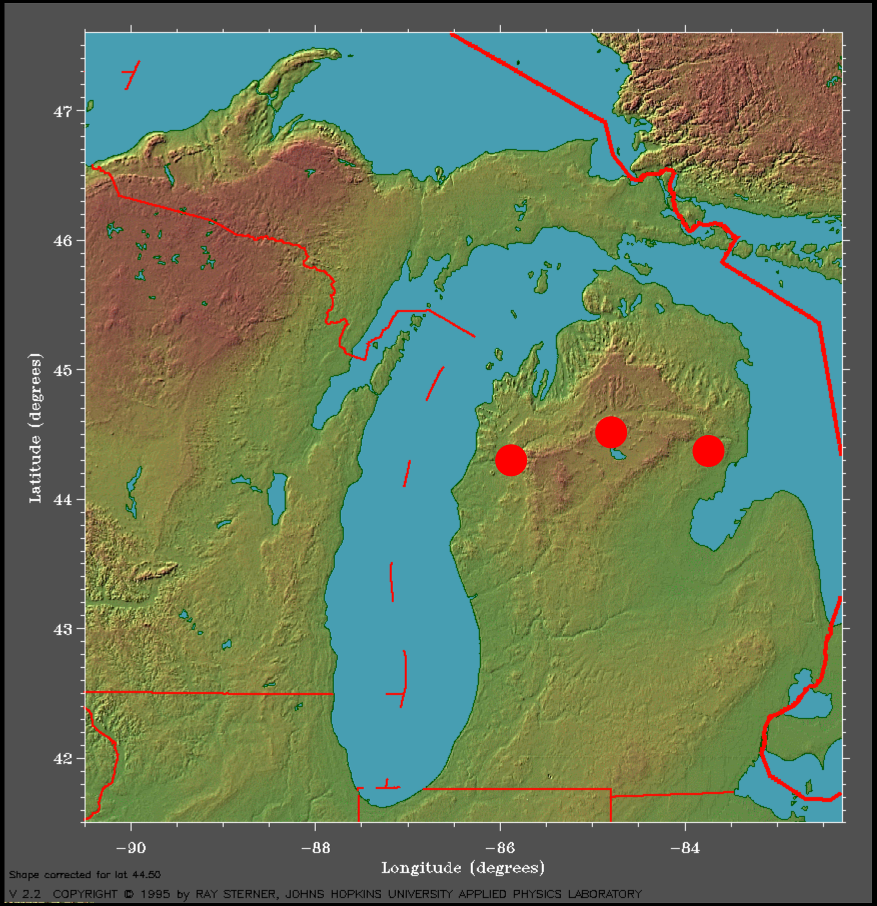
BACKGROUND *continued*:

Phase III: Long-term red pine plantation thinning study (USDA FS NCFES)

- **Plantations established at 3 locations between 1912 and 1931 and thinned to a specified basal area (BA) on about a 10-year cycle, beginning in 1951 (Sarnecki 1990)**
- **Basal areas ranged from 30-160 square feet per acre**

BACKGROUND *continued*:

1989 STUDY SITES



BACKGROUND *continued*:

- Measurements of natural oak regeneration in the midstory (1-5 m)

BACKGROUND *continued*:

Mean Values for Midstory Oak Regeneration Under Various Thinning Treatments at Bosom Field, Crawford County, Michigan (Sarnecki 1990, Table 3).

Treatment	Density (No./acre)	Ave. Height (m)	Max Height (m)	Density X Height -	Basal Area (BA) (ft^2/acre)
Uncut	0.00 a*	0.00 a	0.00 a	0.00 a	0.00 a
BA 160	7.33 ab	1.69 bc	2.83 c	12.03 ab	0.24 a
BA 140	0.00 a	0.00 a	0.00 a	0.00 a	0.00 a
BA 120	7.00 ab	1.26 b	1.77 b	8.80 ab	0.09 a
BA 100	13.00 ab	1.70 bc	3.03 c	20.70 ab	0.23 a
BA 80	41.33 b	1.88 cd	4.57 d	78.60 b	1.08 a
BA 60	90.67 c	2.26 d	5.00 d	204.27 c	3.82 b
BA 40	34.00 ab	2.28 d	4.63 d	79.93 b	3.89 b

*Identical letters denote treatments with no significant difference for a particular variable at P=0.05.

BACKGROUND *continued*:

Mean (and Standard Error) Values for Midstory Oak Regeneration Under Various Thinning Treatments at Bosom Field, Crawford County, Michigan (Sarnecki 1990, Table 8).

Treatment	Age (yrs)	Radial Growth (mm/yr)	Max Height Increment (m/yr)	-
BA 140	7.2 (1.47)	0.425 (0.04)	0.127 (0.03)	
BA 100	10.4 (0.40)	0.660 (0.04)	0.167 (0.02)	
BA 40	17.0 (0.55)	1.554 (0.12)	0.466 (0.03)	

*Denotes a mean significantly different from the other treatment means for a particular variable at P=0.05.

BACKGROUND *continued*:

Phase IV: Controlled, replicated experiment (1990-)

- **Initial design called for planting pines and oaks in the understory of oak and pine stands on good, intermediate, and poor quality sites with various levels of overstory and understory manipulation, and including fire as a treatment**

BACKGROUND *continued*:

- Sites range from glacial till (high quality) through ice contact material (medium quality) to outwash (low quality)
- Due to limited financial resources the study was scaled back to intermediate sites and planting of only oaks
- Fire excluded as a treatment for practical and social reasons

BACKGROUND *continued*:

THE OAK REGENERATION PROBLEM

- WIDESPREAD THROUGHOUT EASTERN U.S.
- MATURE OAK ABUNDANT
- SMALL OAK SEEDLINGS OFTEN ABUNDANT
- LARGE OAK SAPLINGS AND POLES LACKING

BACKGROUND *continued*:

HEAVY MORTALITY BETWEEN SMALL SEEDLING AND LARGE SAPLING SIZE CLASSES

- WOODY COMPETITORS IN UNDERSTORY AND MIDDLESTORY
- DEER BROWSING
- FROST DAMAGE

BACKGROUND *continued*:

POTENTIAL SOLUTIONS

- **REDUCE THE ABUNDANCE OF COMPETITORS**
  (e.g., Crow 1988; Hill and Dickmann 1988; Johnson et al. 1989;
  Lorimer 1989; Loftis 1990; Teclaw and Isebrands 1991; Gordon et al. 1995;
  Brose and Van Lear 1998; Buckley et al. 1998; Weigel and Johnson 1998)

- **LARGER, HIGHER-QUALITY OAK SEEDLINGS**
  (e.g., Gottschalk and Marquis 1983; Kormanik et al. 1997; Zaczek et al. 1997;
  Buckley 2001)

- **RELY ON COPPICE REGENERATION**
  (e.g., Little 1938; Haney 1962; Sander 1971; Johnson 1977; McGee 1978;
  Johnson 1979; Reich et al. 1980; Lamson 1983; Johnson and Rogers 1984;
  Lowell et al. 1989; Weigel and Johnson 1998)

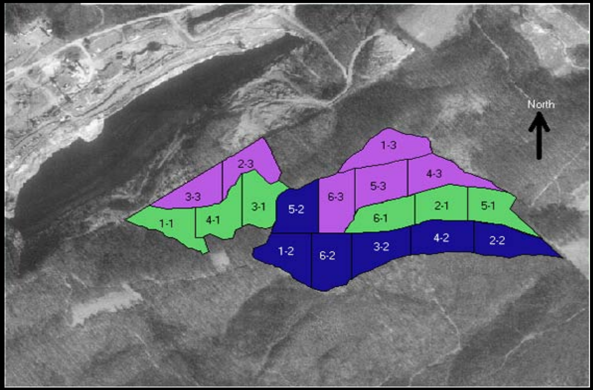
BACKGROUND *continued*:

INVOLVEMENT IN FIVE OAK SHELTERWOOD STUDIES

- **NORTHERN WISCONSIN 1989-1993 (2 studies, on rich and intermediate sites)**

- **NORTHERN LOWER MICHIGAN 1990 (PhD study in oak and pine stands on intermediate sites)**

- **EAST TENNESSEE (1 2002 shelterwood study on intermediate sites and 1 2001 wildlife study on intermediate sites involving partial canopy removal and prescribed fire)**

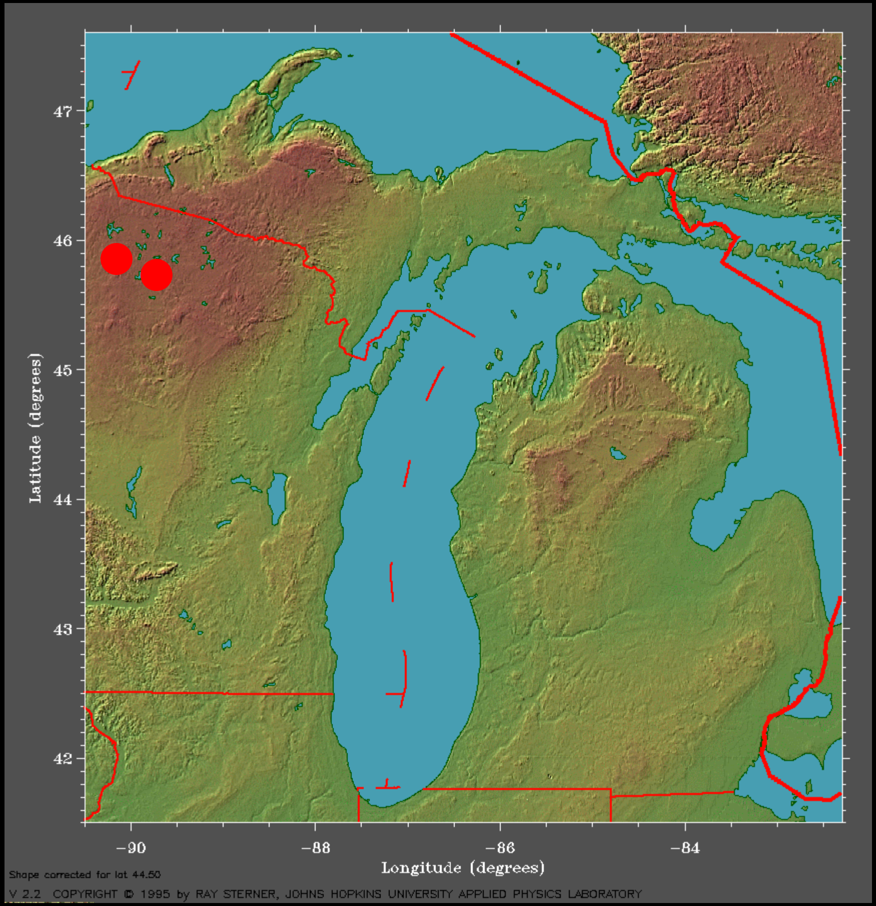


METHODS:

1989-1993 USDA FS SRS STUDY SITES

(J.G. Isebrands, J.C. Zasada, R.M. Teclaw)

- NORTHERN WISCONSIN



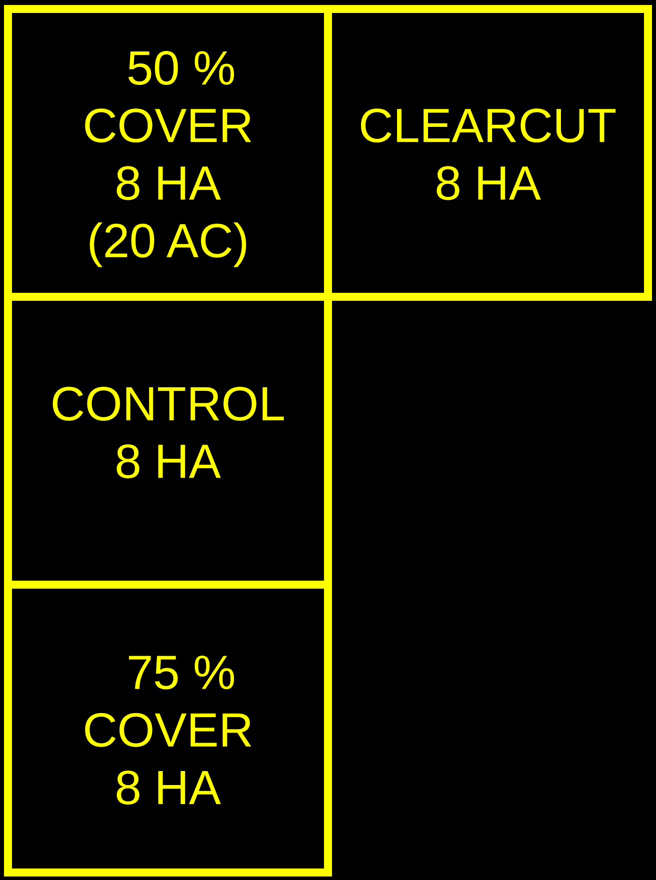
METHODS:

FS STUDY SITES

- MATURE NORTHERN RED OAK STANDS
- CHEQUAMEGON NF AND WISCONSIN STATE FOREST LAND
- CHEQUAMEGON SOILS WERE SILT LOAMS
  STATE FOREST SOILS WERE SANDY LOAMS
- CHEQUAMEGON SITE WAS AViO (RICH - MESIC)
  STATE FOREST SOILS WERE AVVib (MEDIUM - DRY-MESIC)

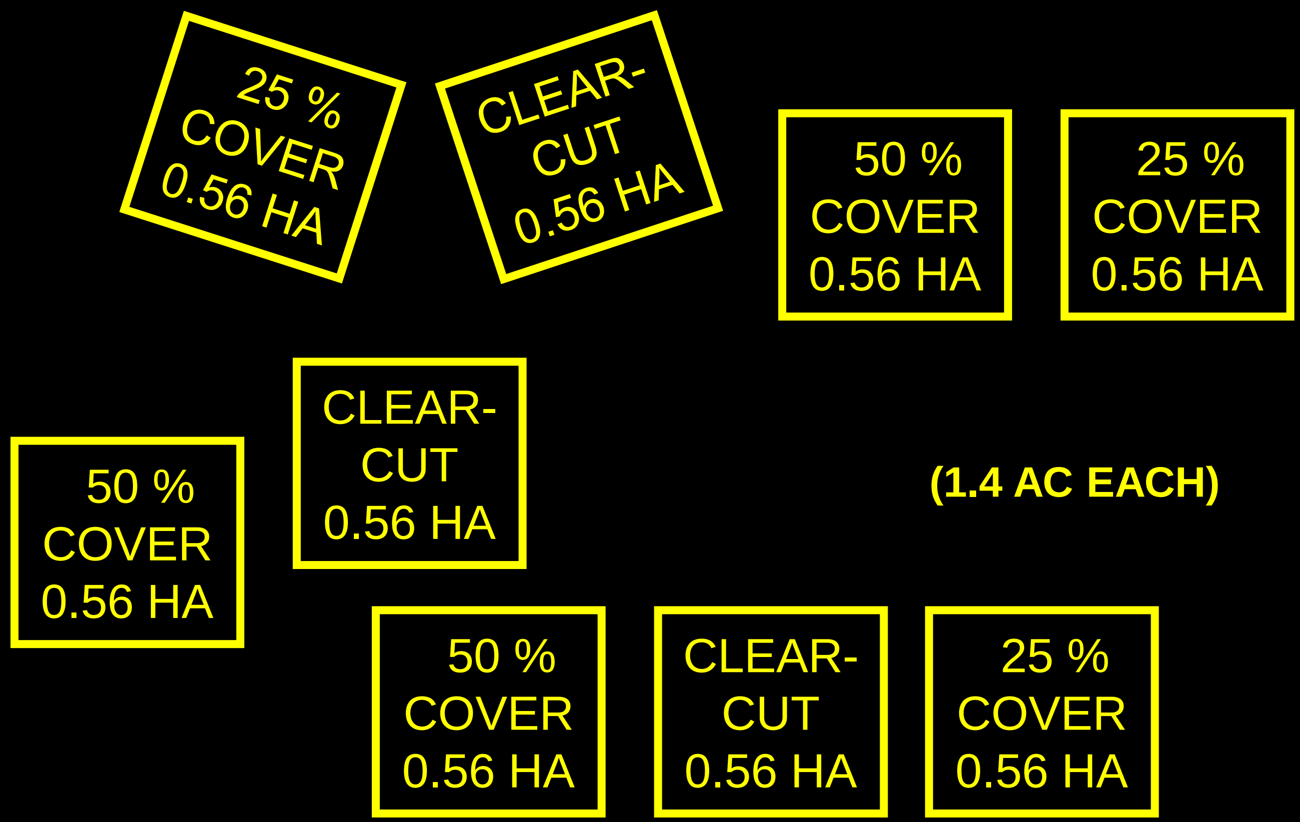
METHODS:

EXPERIMENTAL DESIGN AND TREATMENTS, CHEQUAMEGON NF



METHODS:

EXPERIMENTAL DESIGN AND TREATMENTS, WISCONSIN STATE FOREST LAND



RESULTS:

- GREATER CHANGES IN UNDERSTORY HERB AND SHRUB SPECIES COMPOSITION OCCURRED ON RICH THAN INTERMEDIATE SITES

- ON RICH SITE AFTER 4 YEARS, RASPBERRY DOMINATED CLEARCUT AND 50% COVER PLOTS, DISCING STIMULATED ASPEN, AND BEAKED HAZEL DOMINATED UNCUT PLOT

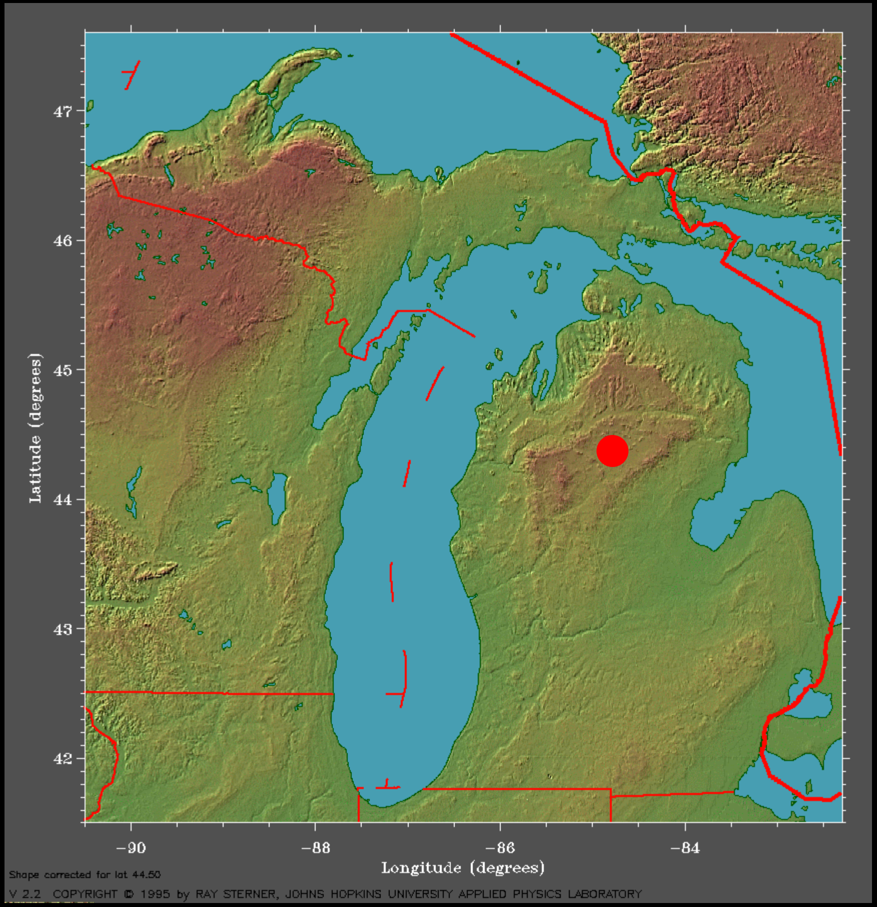
- SPRAYING OF SEDGES ON INTERMEDIATE SITE RELEASED WOODY COMPETITORS INCLUDING BEAKED HAZEL AND PAPER BIRCH

- MULTIPLE FROSTS OCCURRED IN CLEARCUT AND LIGHT SHELTERWOODS

METHODS:

1990 STUDY SITES

- CRAWFORD AND ROSCOMMON COUNTIES



METHODS:

STUDY SITES

- NORTHERN RED OAK AND RED PINE PLANTATIONS ESTABLISHED EARLY IN THE 20TH CENTURY FOLLOWING LOGGING OF OLD-GROWTH RED AND WHITE PINE

- MICHIGAN STATE FOREST LAND

- SOILS WERE SANDY MIXED FRIGID ALFIC HAPLORTHODS DEVELOPED IN PITTED OUTWASH

- SITES INTERMEDIATE IN PRODUCTIVITY BETWEEN SITES ON OUTWASH AND SITES ON TILL (SI_{50} FOR NRO = 58 FT, SITES RESEMBLE PArVVb, PArVHa KOTAR TYPES)

METHODS:

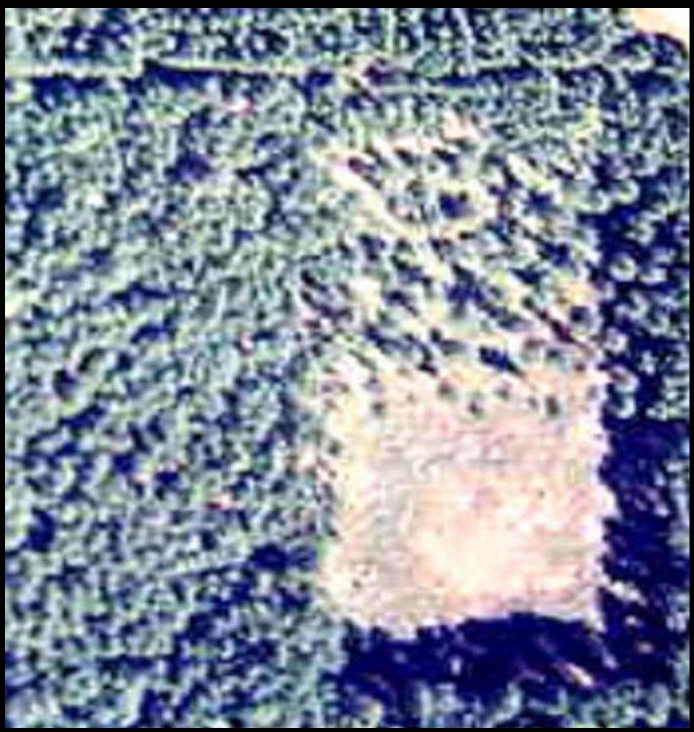
STUDY SITES

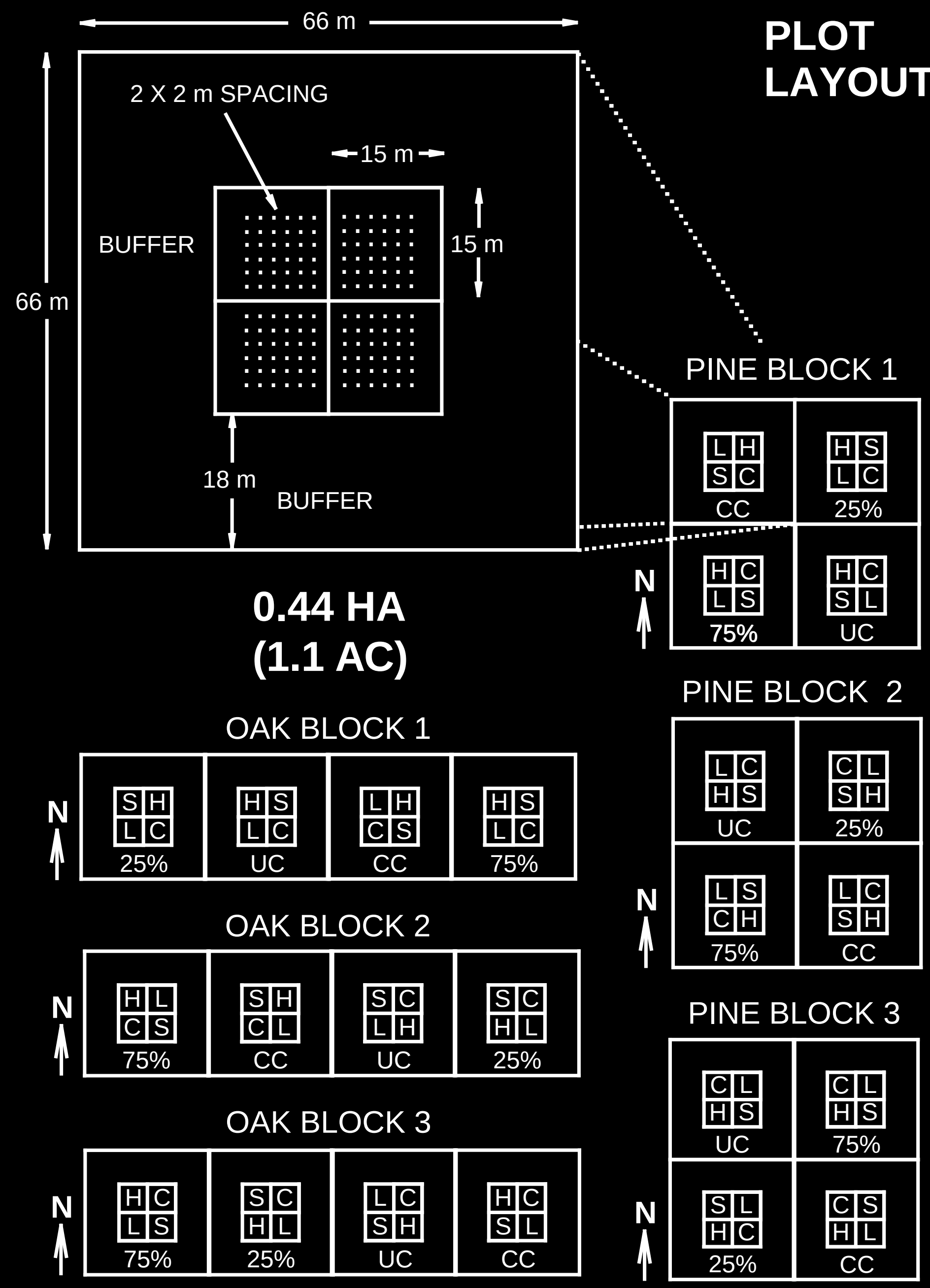
METHODS:

STUDY SITES

METHODS:

EXPERIMENTAL DESIGN AND TREATMENTS





METHODS:

TREATMENTS

- 4 LEVELS OF OVERSTORY REMOVAL

OAK		PINE	
% COVER	BA (FT^2/AC)	%COVER	BA (FT^2/AC)
CC	0	CC	0
25	27	25	39
75	70	75	143
UC	157	UC	184

- 4 UNDERSTORY TREATMENTS

C - CONTROL
L - LITTER REMOVAL
H - HERB LAYER REMOVAL (0-25 CM TALL VEGETATION)
S - SHRUB LAYER REMOVAL (>25 CM TALL, < 2.54 CM DBH)

METHODS:

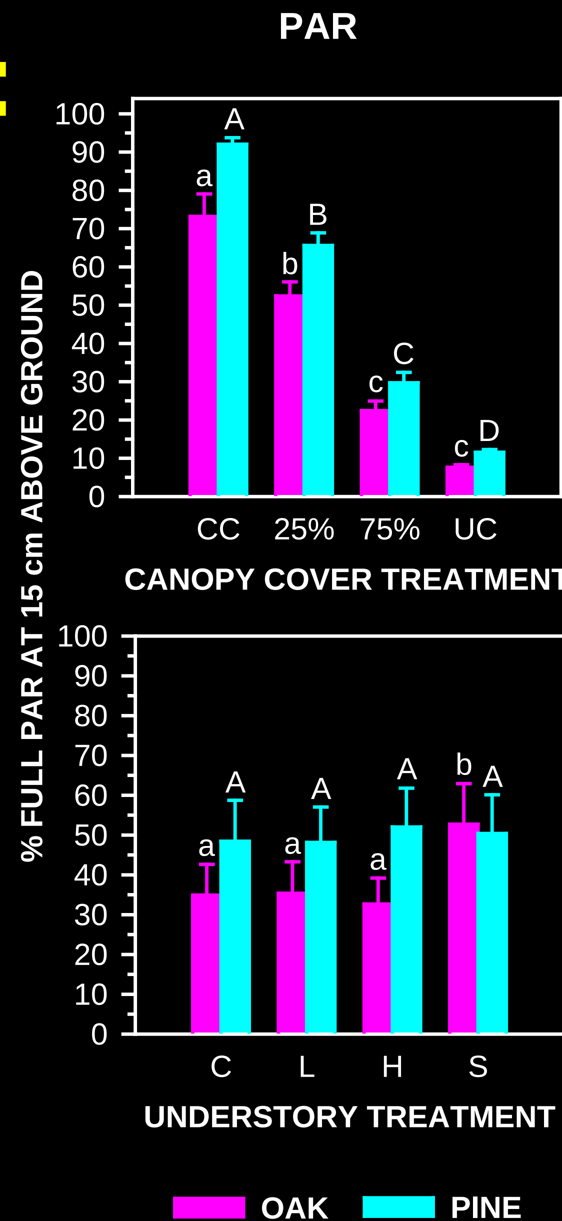
PLANTING

- 20 DIRECT SEEDED LOCATIONS (3 ACORNS / LOCATION)
- 12 2-0 BARE-ROOT NURSERY SEEDLING LOCATIONS
- 5,760 ACORNS IN TOTAL
- 1,152 NURSERY SEEDLINGS IN TOTAL

PROTECTION

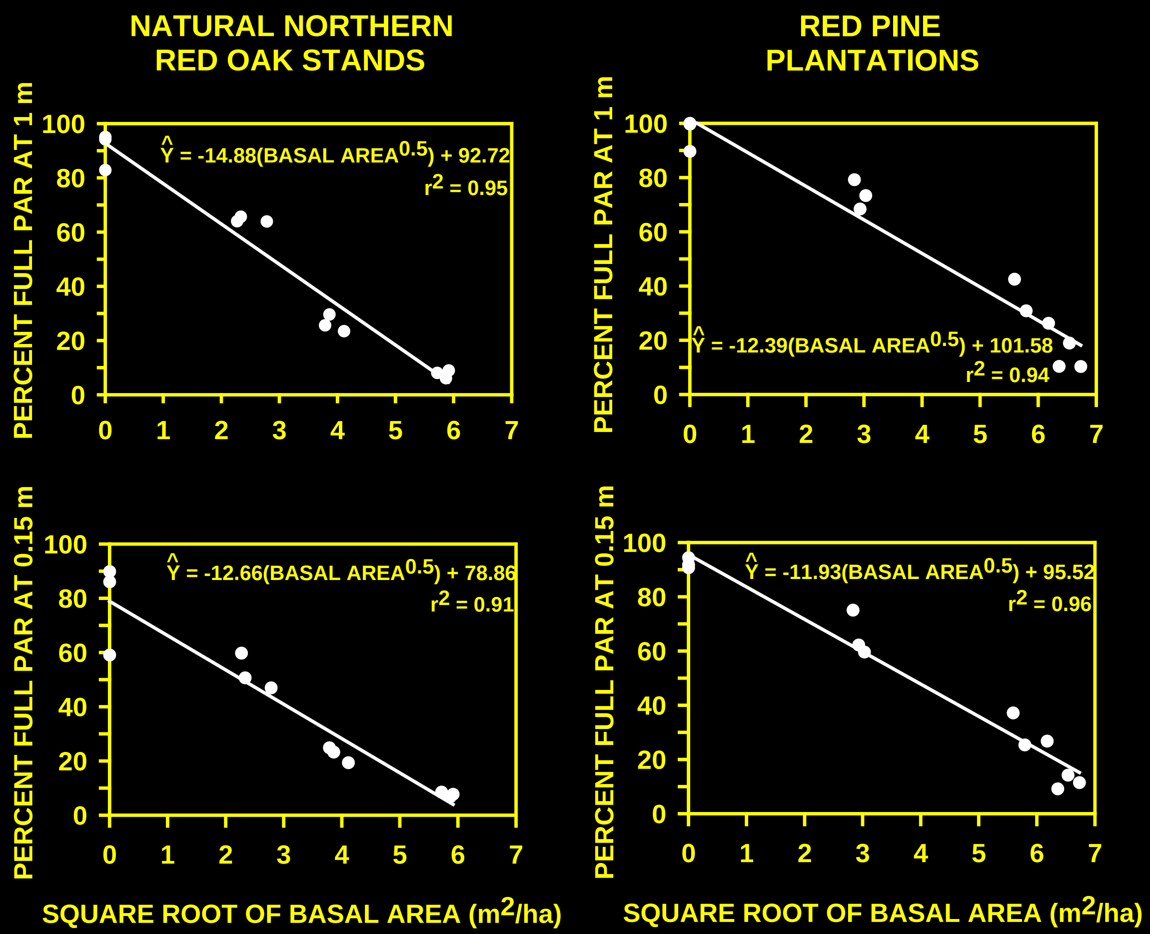
- ROPEL REPELLANT
- 1,152 6 FOOT TALL DEER CAGES
- 1,920 HARDWARE CLOTH DIRECT SEEDING CAGES

1991-92 RESULTS:



1991 - 1992 RESULTS:

PAR - BASAL AREA RELATIONSHIPS



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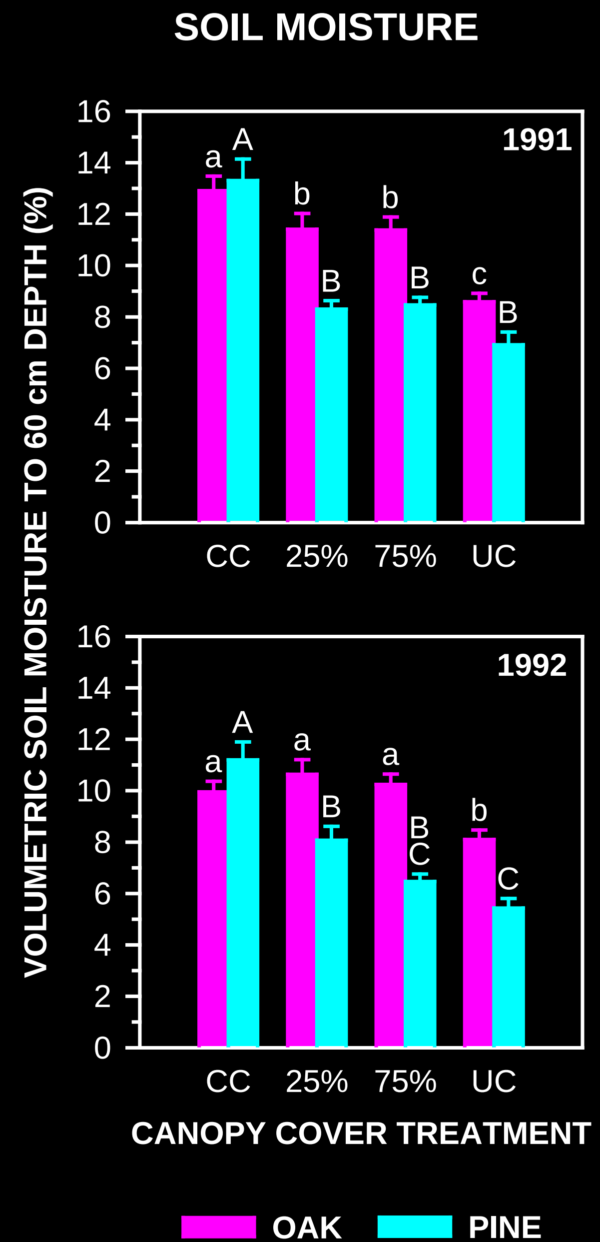

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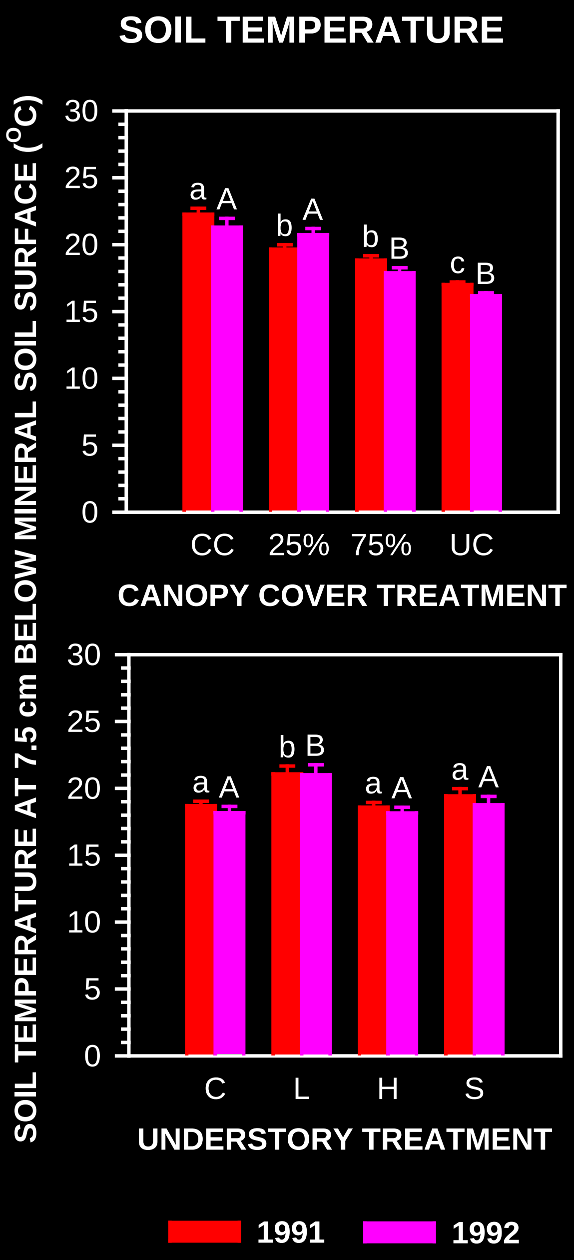

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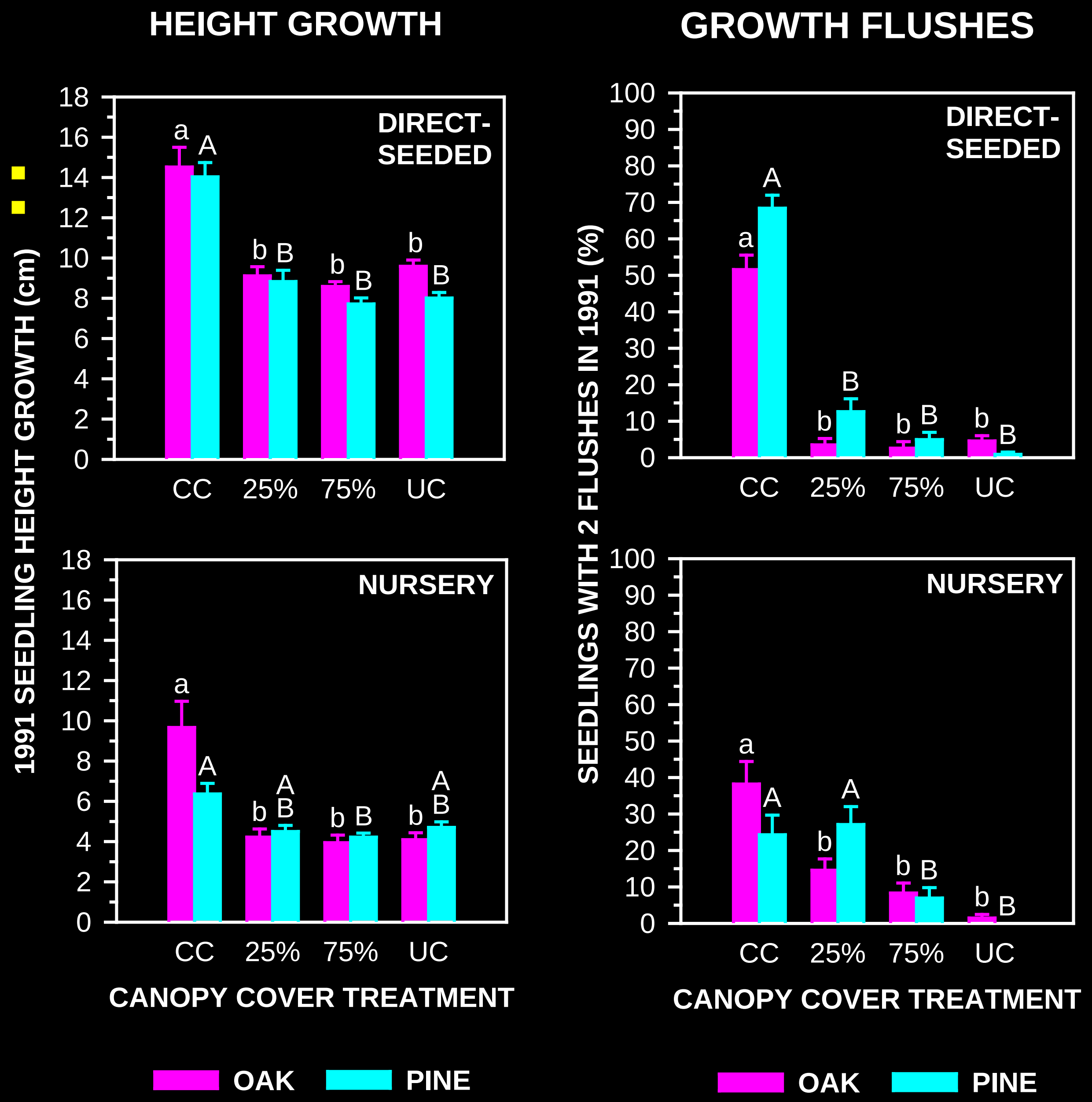

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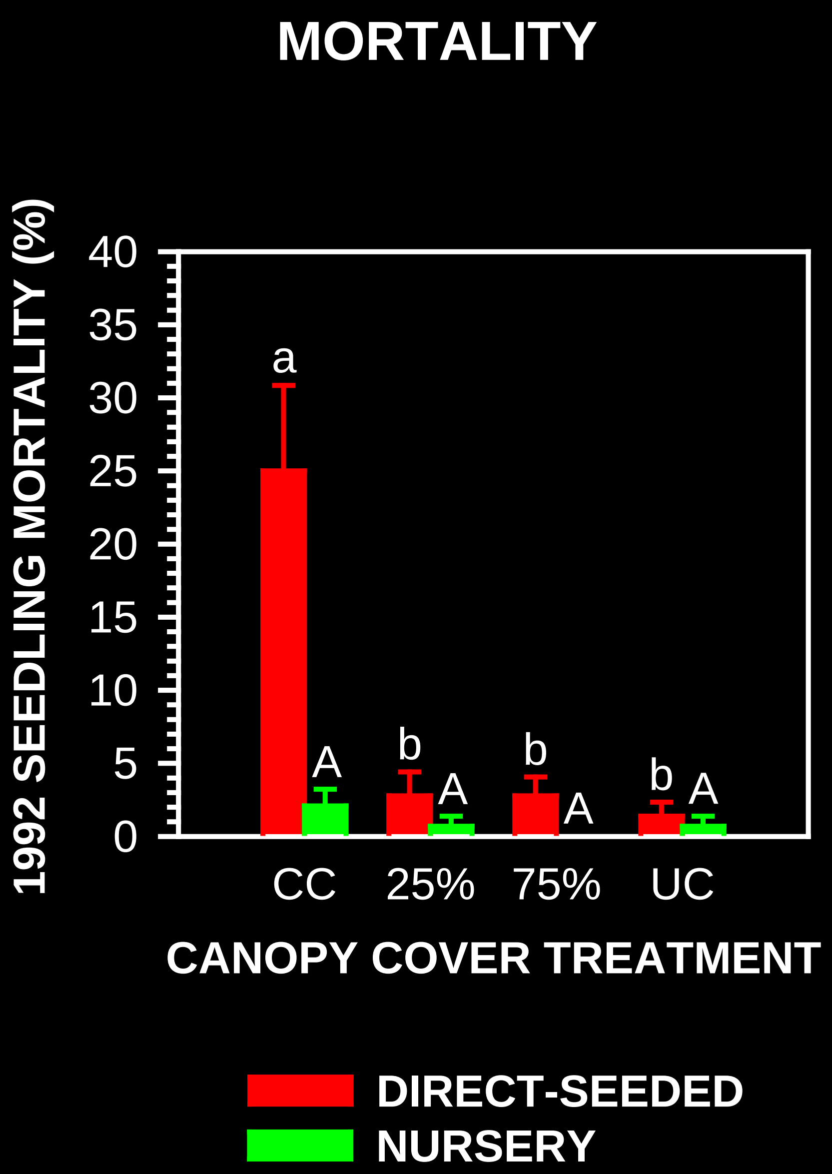

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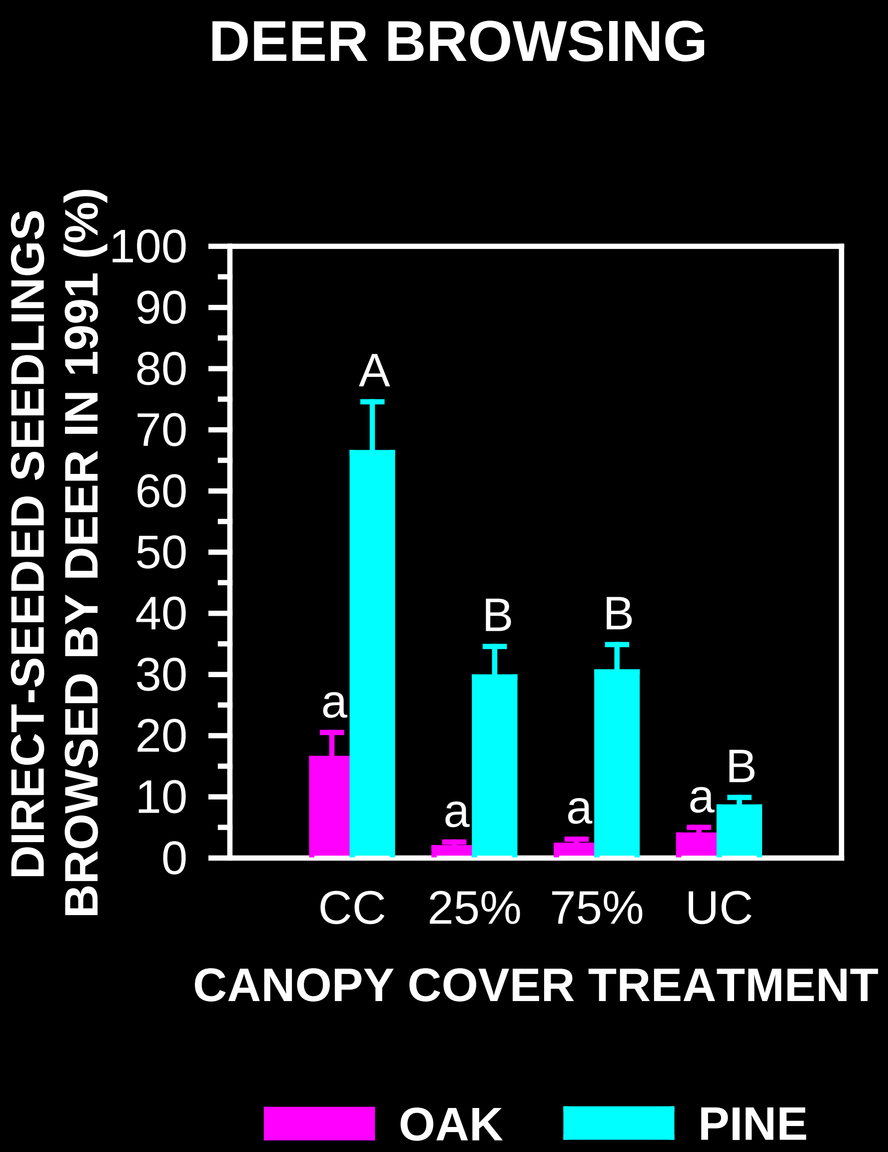
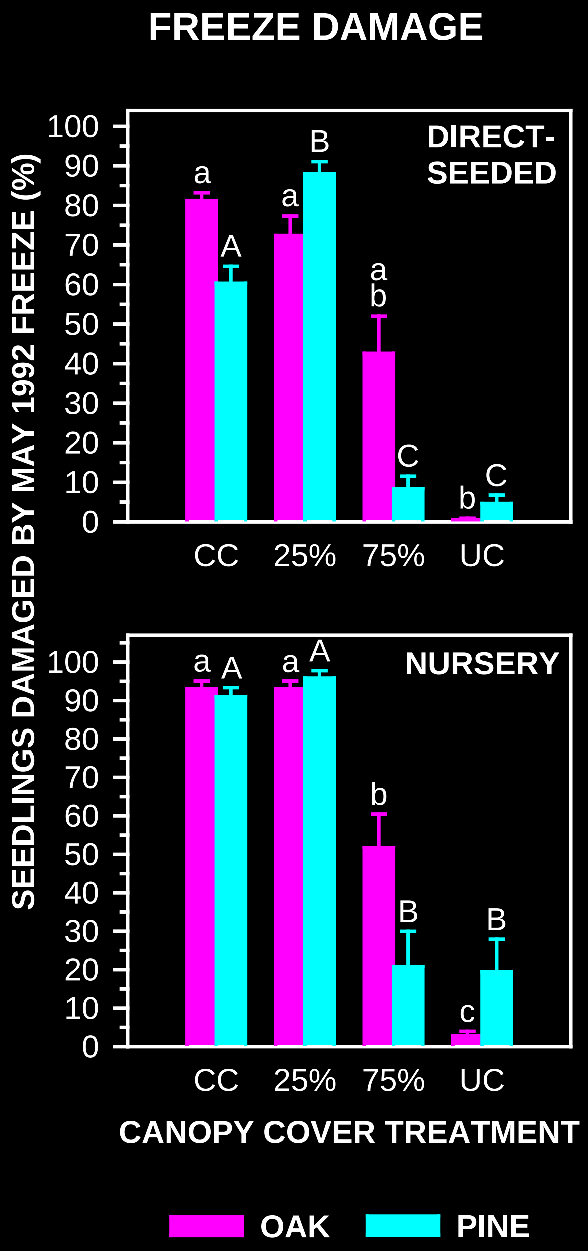


1991-92 RESULTS:



1991-92 RESULTS:

MEAN PERCENTAGES OF SEED SPOTS WITH 1-3 ACORNS REMOVED BY RODENTS

	Pine stand 1	Pine stand 2	Pine stand 3	Treatment means
Overstory treatments (%)				
Clearcut	0.0* (0.0)[††]	35.0 (10.8)	0.0 (0.0)	11.7[a§] (5.9)
50% Cover	63.8 (8.8)	52.5 (6.0)	3.8 (2.4)	40.0[ab] (8.5)
75% Cover	62.5 (9.7)	73.8 (4.7)	7.5 (1.4)	47.9[ab] (9.3)
Uncut	67.5 (2.5)	85.0 (6.8)	25.0 (3.5)	59.2[b] (8.0)
Understory treatments (%)				
Control	52.5[†] (17.5)	56.3 (17.5)	8.8 (4.3)	39.2[a] (10.0)
Litter	41.3 (15.1)	55.0 (6.8)	6.3 (4.7)	34.2[a] (8.1)
Herb	40.0 (13.7)	60.0 (15.5)	13.8 (7.5)	37.9[a] (8.8)
Shrub	60.0 (20.3)	75.0 (6.1)	7.5 (6.0)	47.5[a] (11.0)

* Means for overstory treatments within individual pine stands are calculated over 4 understory treatment plots.

[†] Means for understory treatments within individual pine stands are calculated over 4 overstory treatment plots.

[††] One standard error is presented in parentheses.

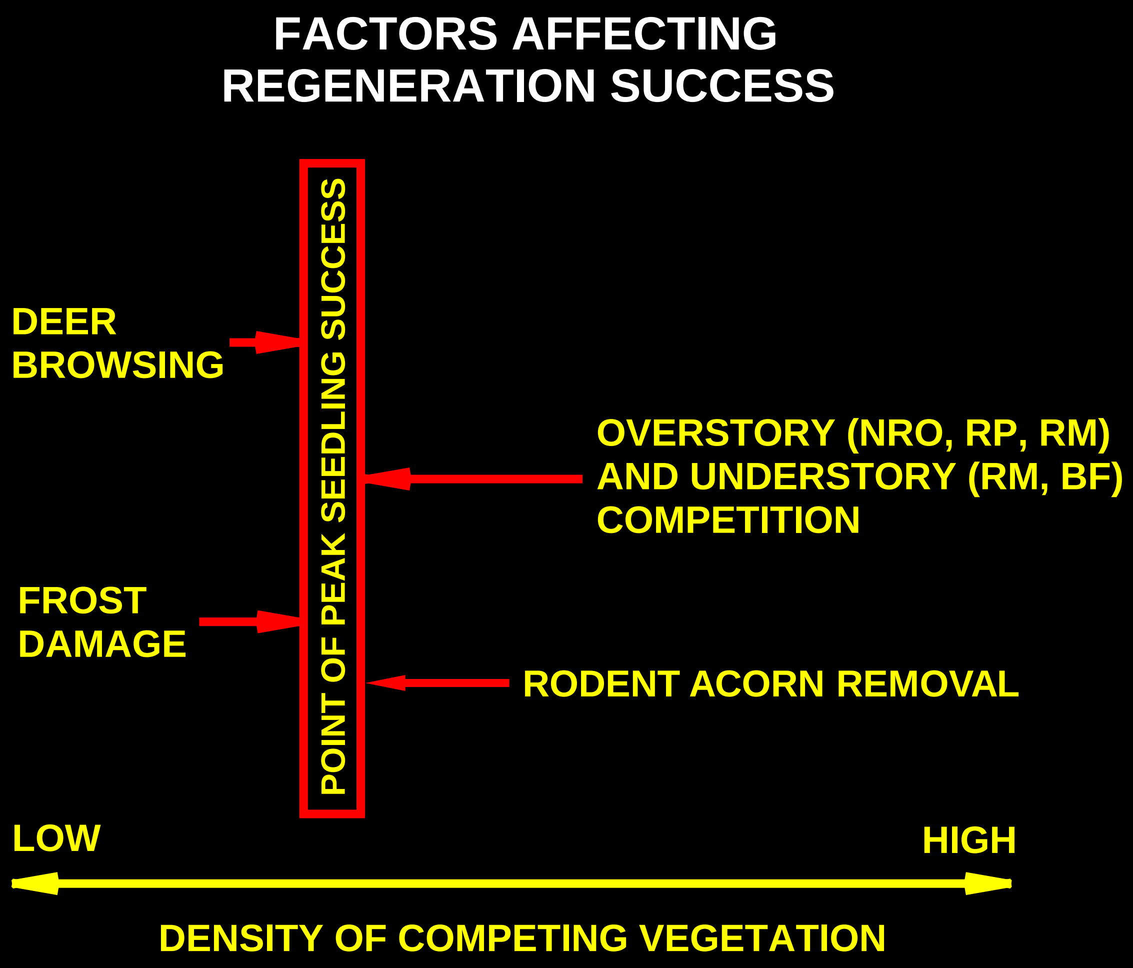
[§] Within sets of overstory and understory treatments, treatment means (n = 3 stands) with the same letters are not significantly different based on Tukey's HSD (?Alpha = 0.05).

EARLY CONCLUSIONS:

- CLEARCUTS HAD THE HIGHEST LEVELS OF PAR AND SOIL MOISTURE, AND OFFERED THE HIGHEST POTENTIAL FOR OAK SEEDLING AND SAPLING GROWTH

- CLEARCUTS ALSO HAD THE HEAVIEST DEER BROWSING AND FREEZE DAMAGE, BOTH OF WHICH RESULTED IN THE HIGHEST LEVELS OF OAK MORTALITY

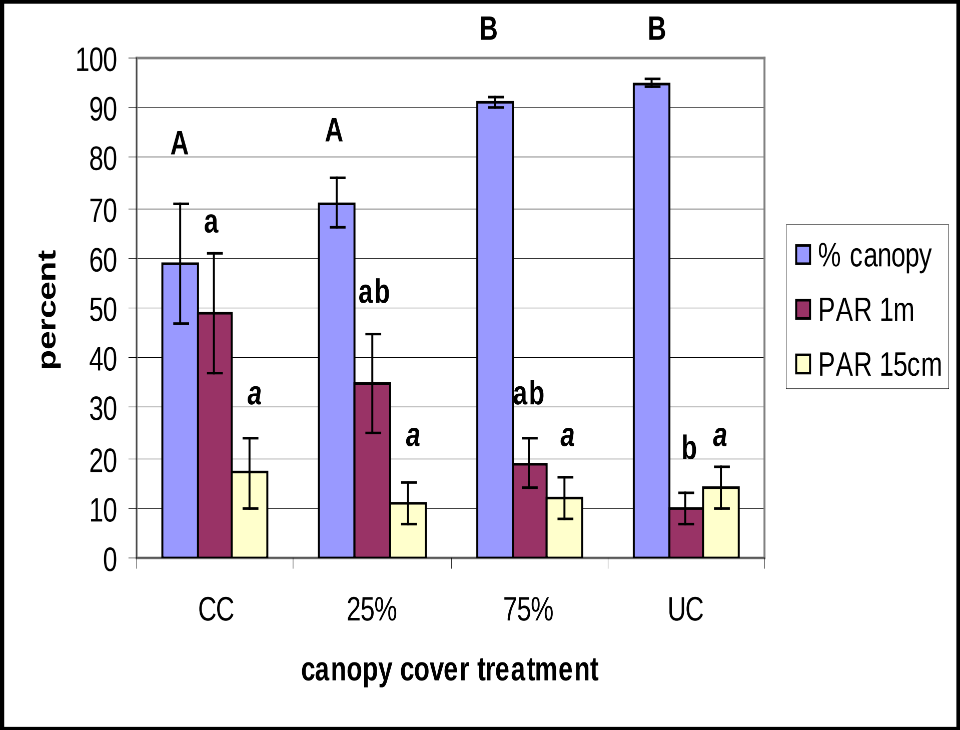
EARLY CONCLUSIONS:



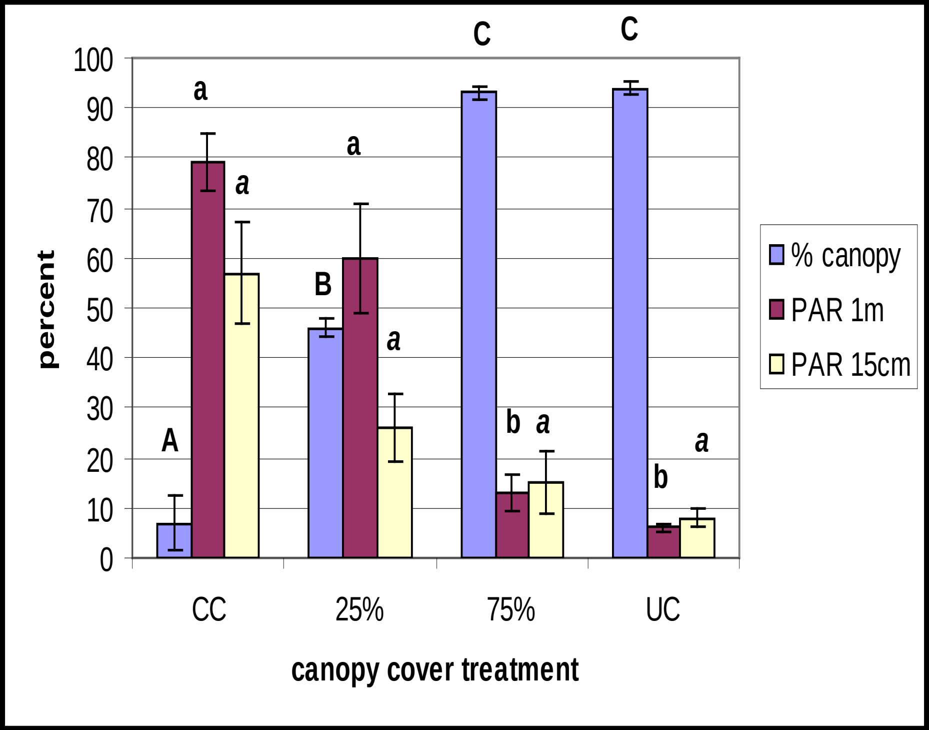
2001 RESULTS:

CANOPY COVER AND PAR

OAK STANDS



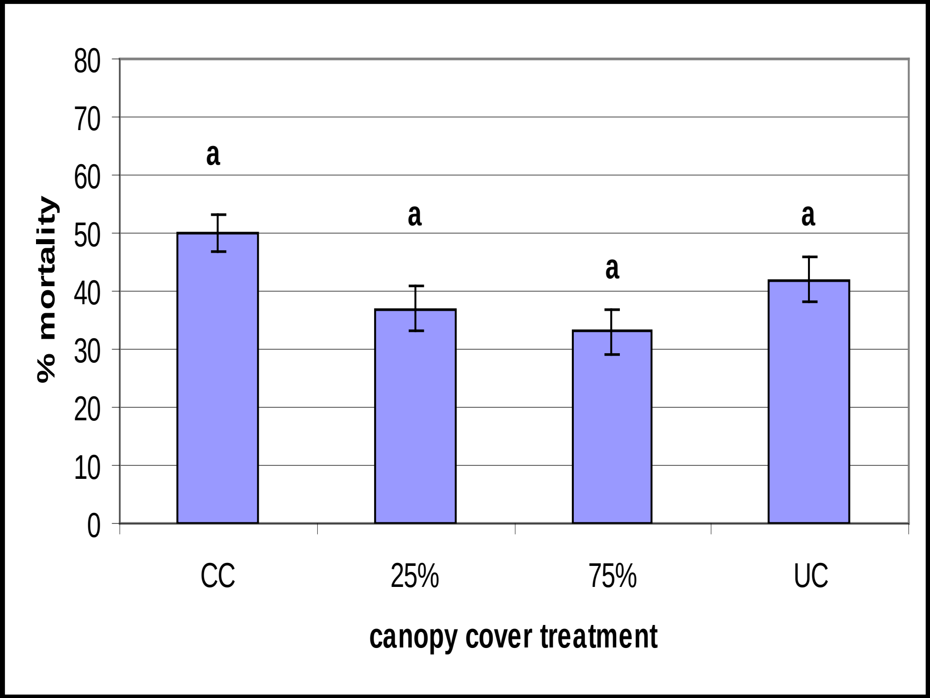
PINE STANDS



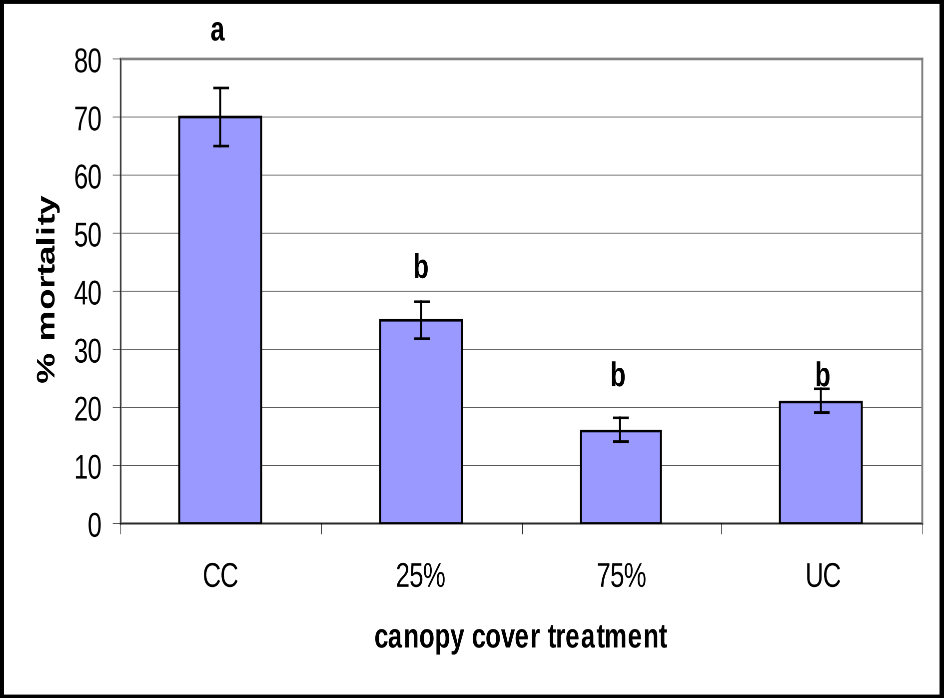
2001 RESULTS:

PLANTED OAK MORTALITY 1991-2001

OAK STANDS



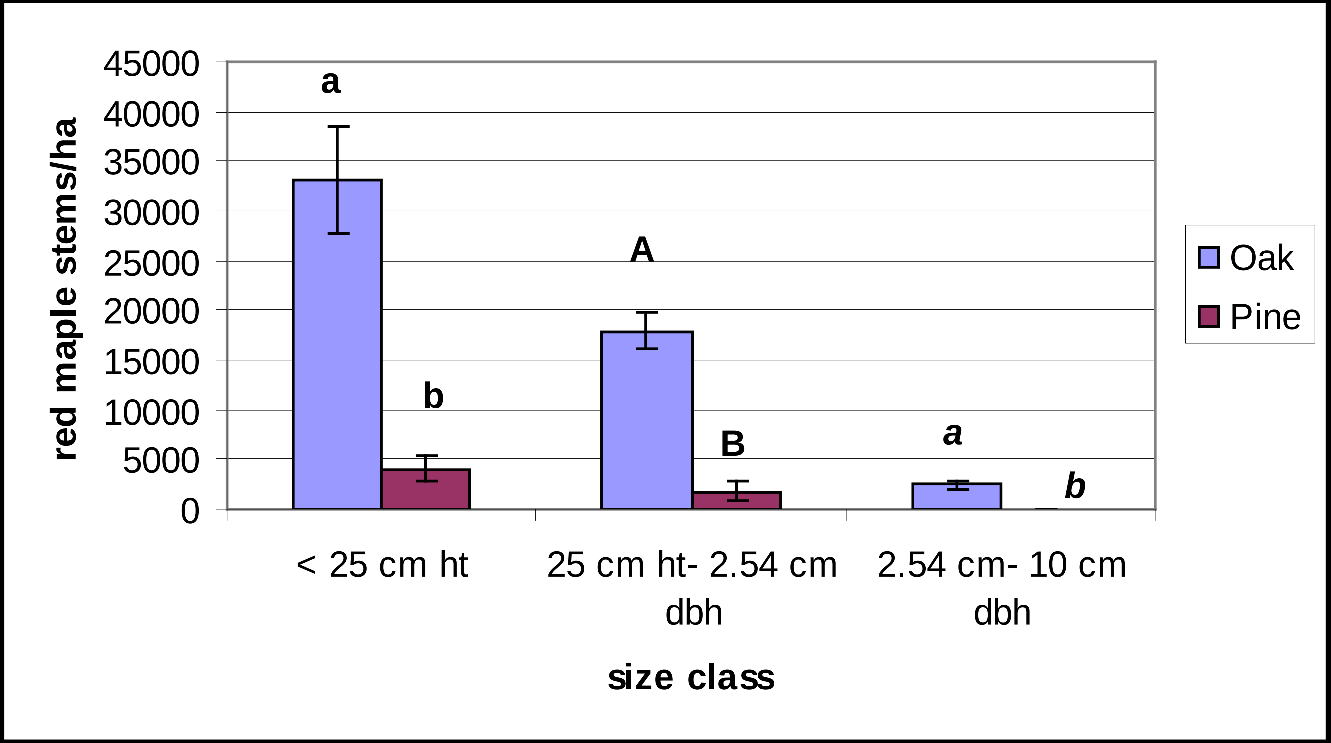
PINE STANDS



2001 RESULTS:

10-YEAR RED MAPLE DEVELOPMENT

2001 RED MAPLE DENSITY WITHIN OAK AND PINE STANDS



2002 PRESCRIBED BURNING

GOALS

- THREE FOOT FLAME LENGTHS
- TOP-KILL OR TORCH ALL REGENERATION
- BURN WHILE RED MAPLE IS MOST SUSCEPTIBLE TO INCREASE COMPLETE MORTALITY

OAK STAND BURN CONDITIONS

- MAY 15, 2002
- 65º F
- RH 34%
- 1 MPH SW WIND
- NORTH FACING 5% SLOPES

OAK STAND FIRE BEHAVIOR

- CONSIDERABLE AMOUNT OF BACKING FIRE
- 0.5 - 2 FT FLAME LENGTHS
- SOME TORCHING OF WHITE PINE
- ONE UNDERSTORY PLOT REMAINED UNBURNED

PINE STAND BURN CONDITIONS

- MAY 21, 2002
- 52º F
- RH 31%
- 2 MPH W-NW WIND
- NO SLOPE

PINE STAND FIRE BEHAVIOR

- **1-3 FT FLAME LENGTHS**
- **TORCHING OF MID-STORY BALSAM FIR**
- **SLOW SPREAD IN CLEARCUTS**
- **TENDED TO CLIMB PINE BARK**

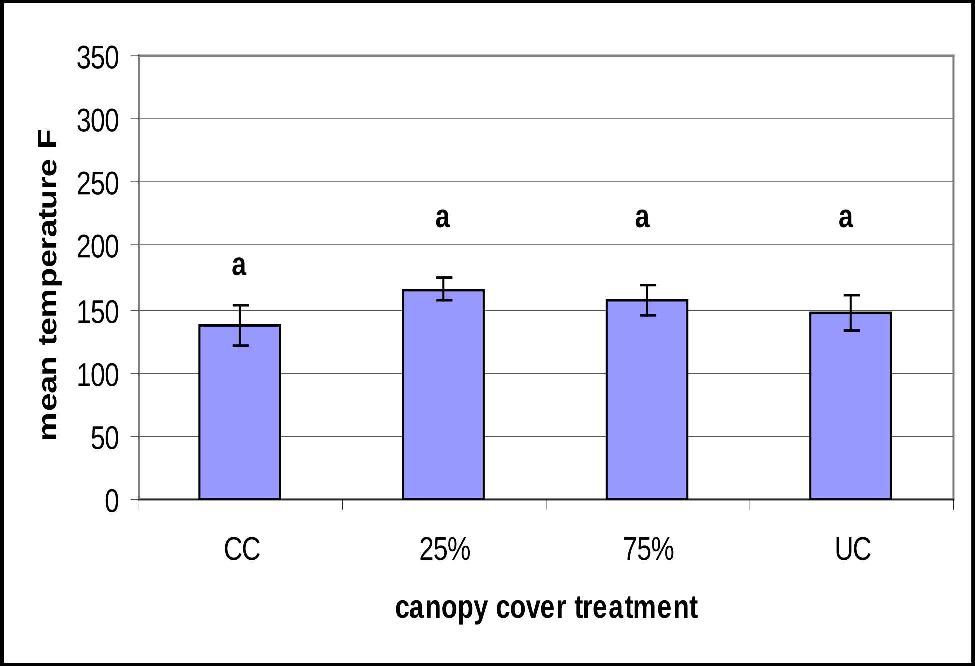
TEMPERATURE INDICATING PAINTS

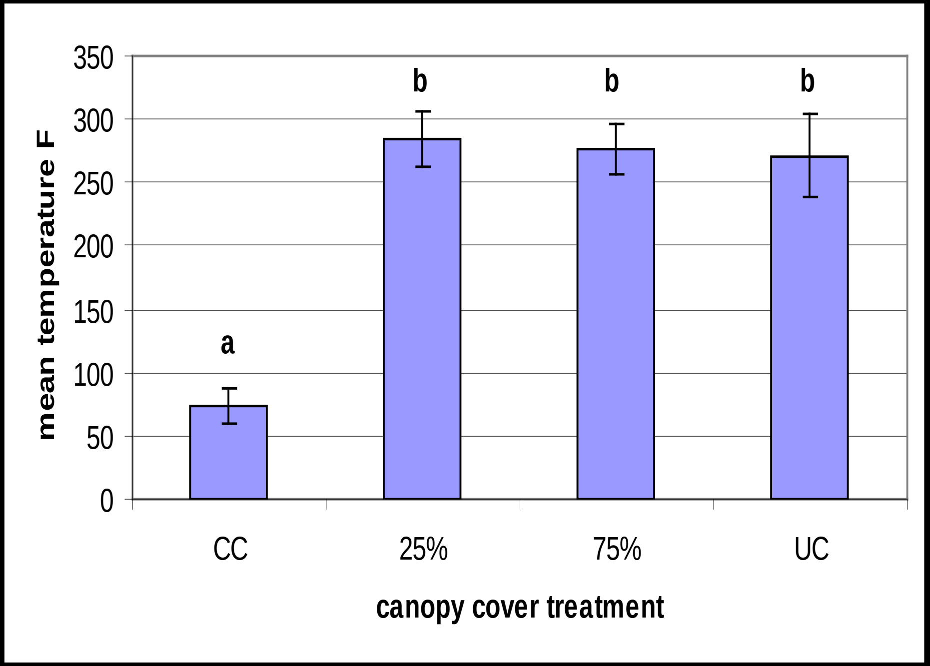
- 175º F
- 300º F
- 400º F
- 500º F
- 600º F
- 700º F
- 1100º F
- 1500º F

FIRE TEMPERATURE VARIABILITY

(2 ft above the ground)

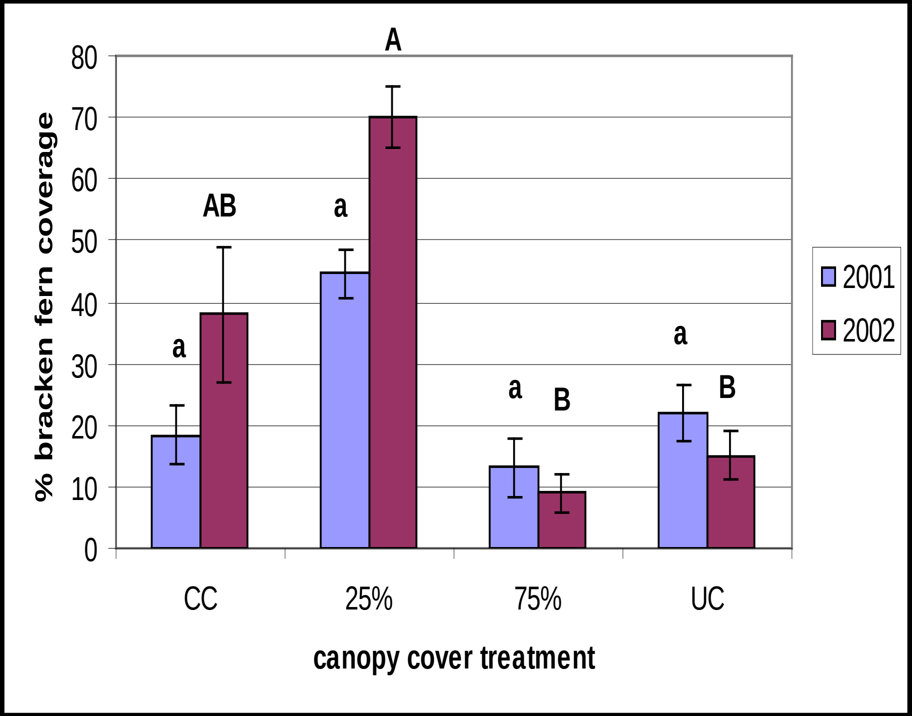
Oak stand mean temp = 152º F (A) **Pine stand mean temp = 227ºF (B)**





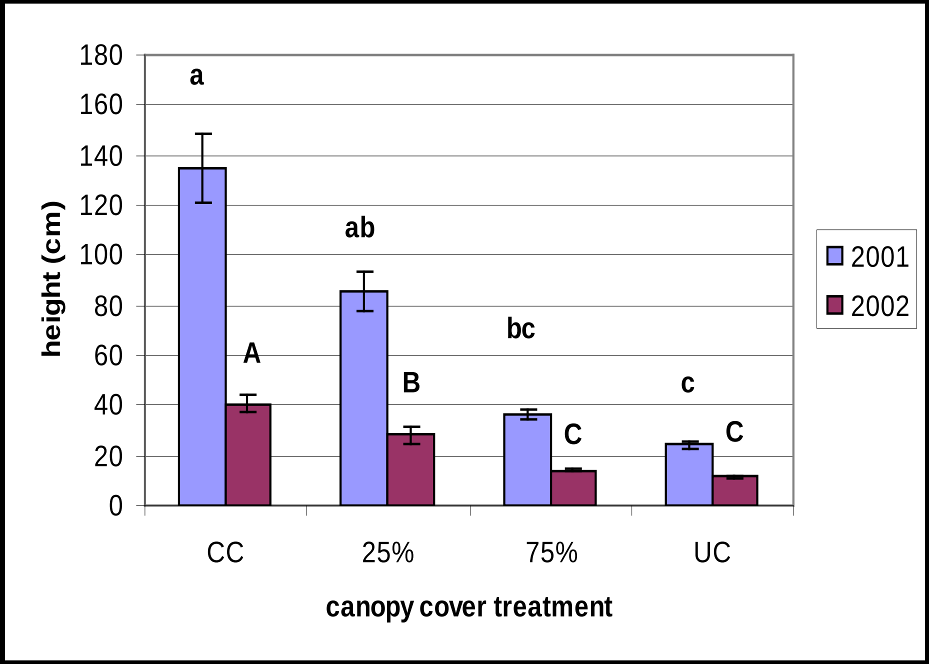
FIRE EFFECTS ON BRACKEN FERN

CC AND 25% COVER PLOTS

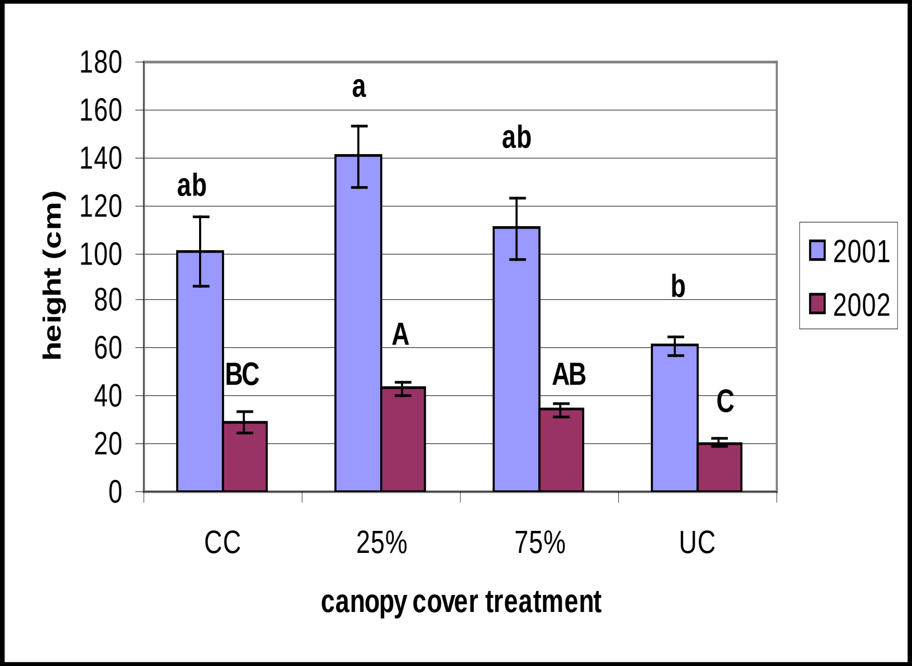


CAGED PLANTED OAK SAPLINGS AND SPROUTS

OAK STANDS



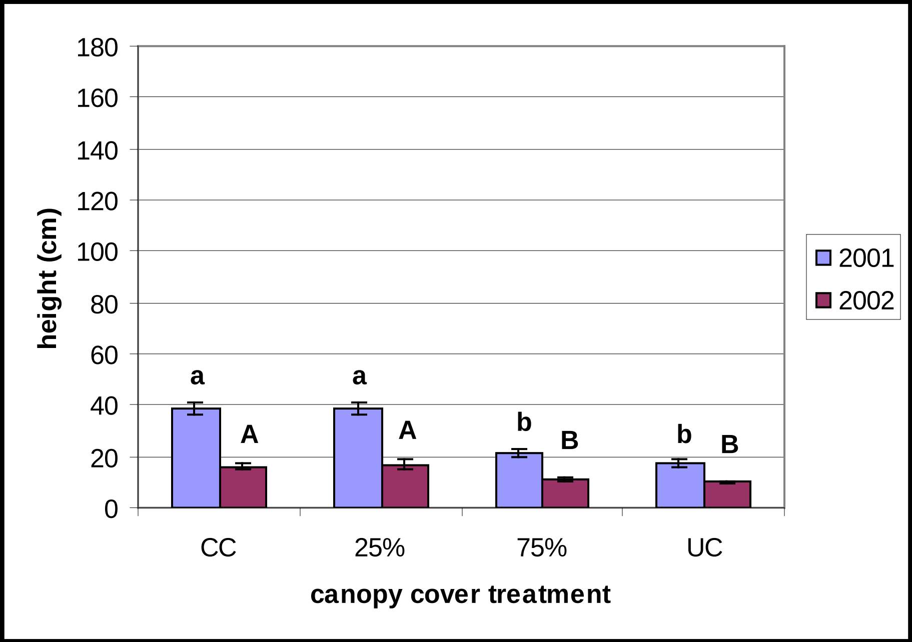
PINE STANDS



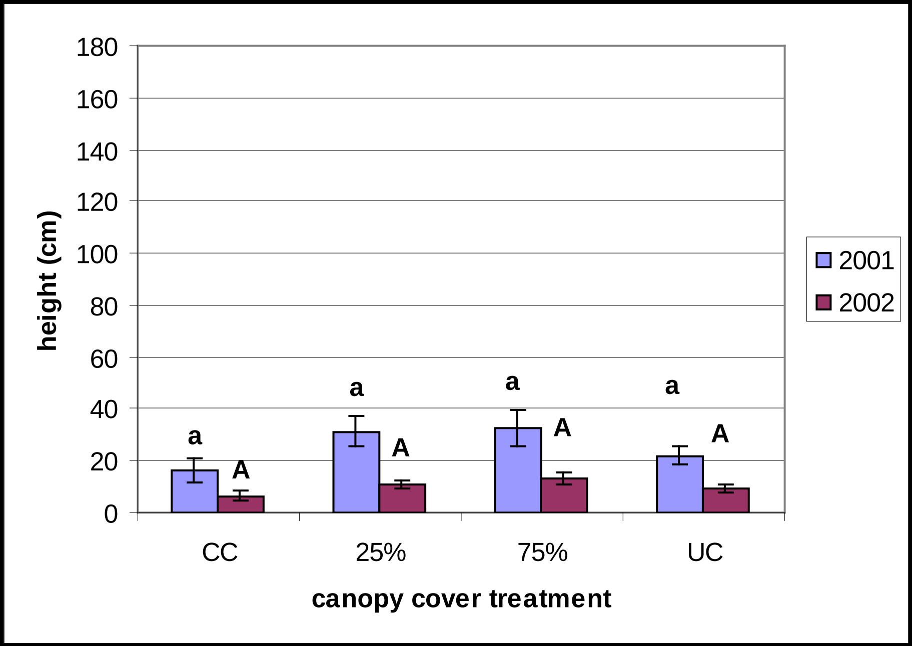
BROWSING OF NEW OAK SPROUTS

UNCAGED PLANTED OAK SAPLINGS AND SPROUTS

OAK STANDS



PINE STANDS



FIRE EFFECTS ON RED MAPLE

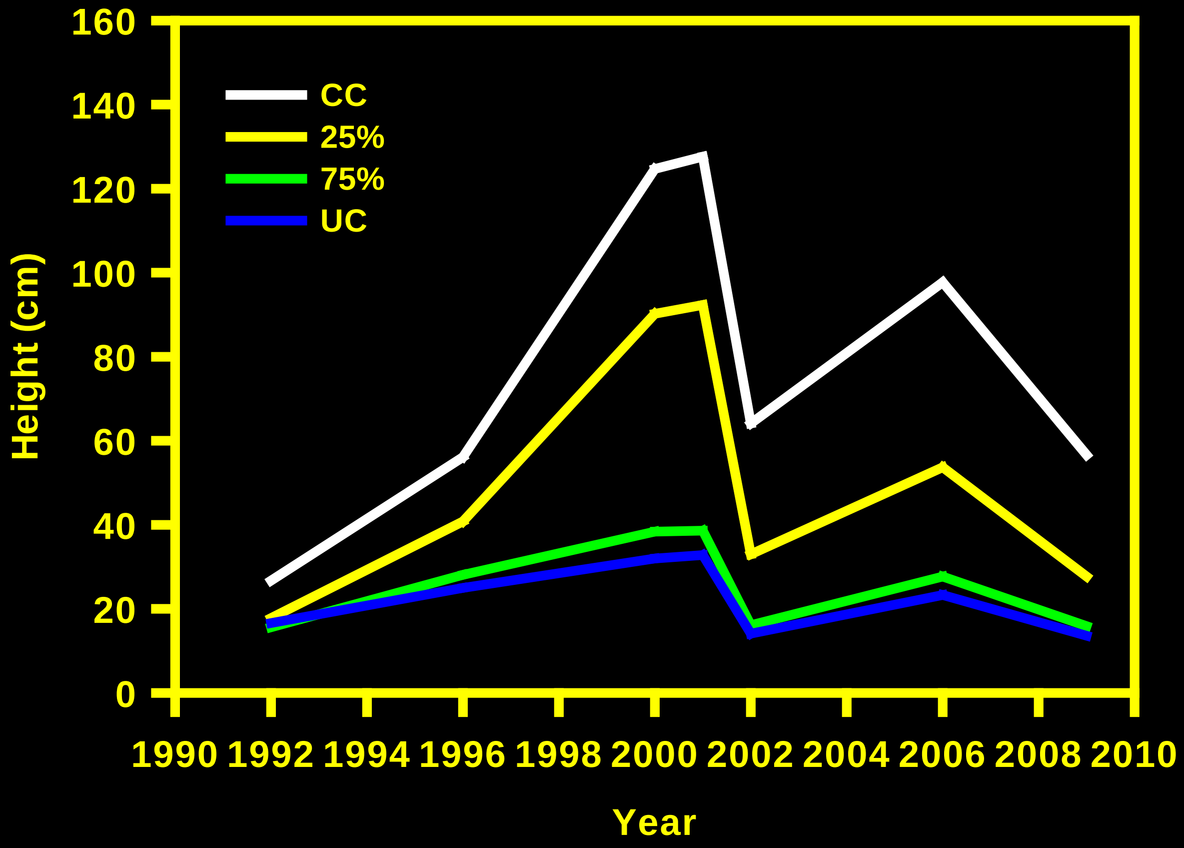
2008 PRESCRIBED BURNING

GOALS

- THREE FOOT FLAME LENGTHS
- TOP-KILL OR TORCH ALL REGENERATION
- BURN WHILE RED MAPLE IS MOST SUSCEPTIBLE TO INCREASE COMPLETE MORTALITY

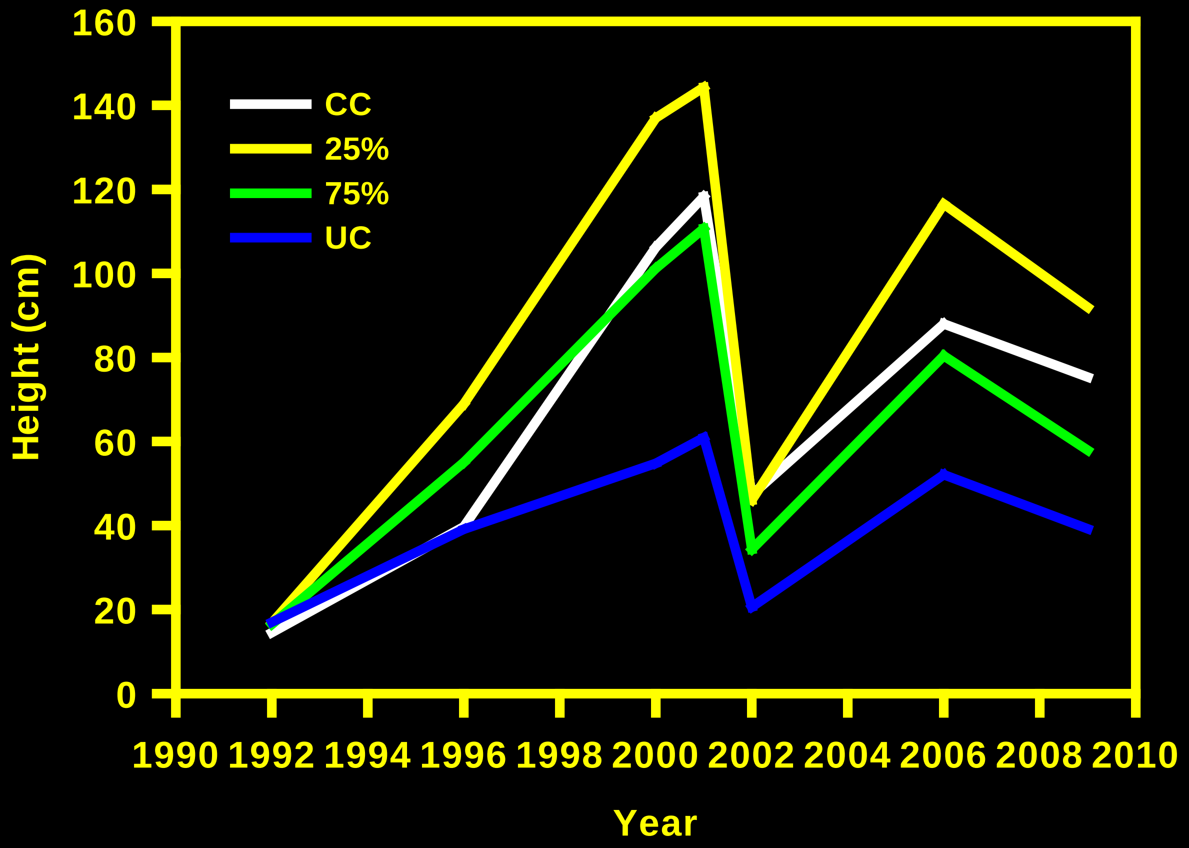
1992-2009 RESULTS

CAGED DIRECT-SEEDED AND NURSERY SEEDLINGS COMBINED,
OAK STANDS



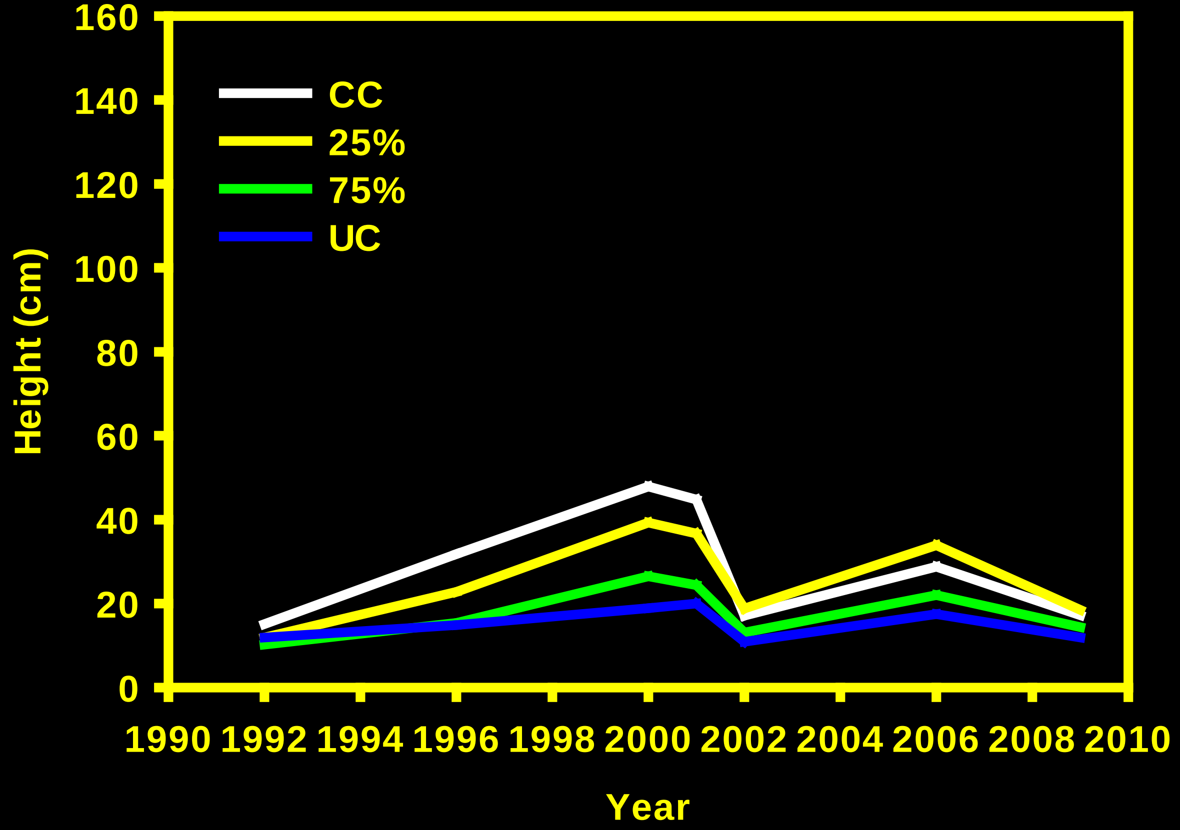
1992-2009 RESULTS

CAGED DIRECT-SEEDED AND NURSERY SEEDLINGS COMBINED, PINE STANDS



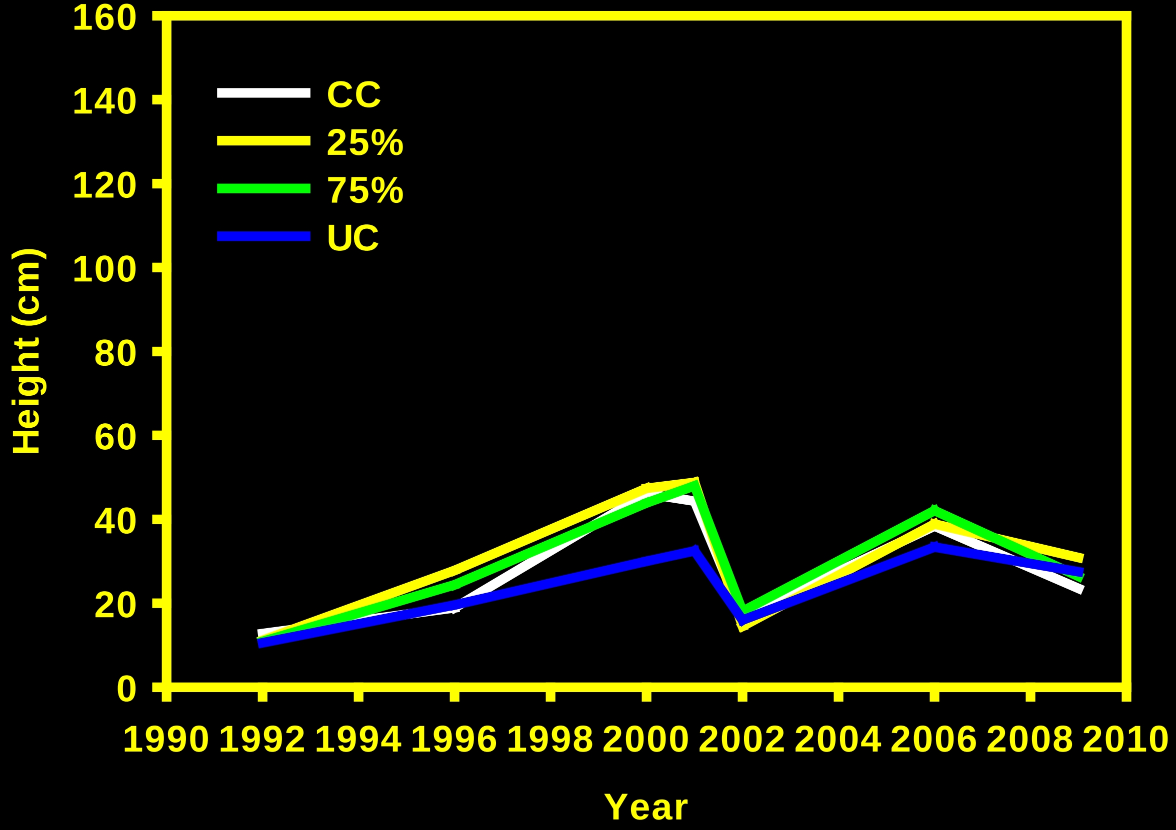
1992-2009 RESULTS

UNCAGED DIRECT-SEEDED AND NURSERY SEEDLINGS COMBINED,
OAK STANDS



1992-2009 RESULTS

UNCAGED DIRECT-SEEDED AND NURSERY SEEDLINGS COMBINED, PINE STANDS



EMERGING CONCLUSIONS:

- MATURE PINE STANDS ARE ACCUMULATORS OF OAK SEEDLINGS AND SAPLINGS AND MATURE OAK STANDS ARE ACCUMULATORS OF SEEDLINGS AND SAPLINGS OF RED MAPLE AND OTHER SHADE-TOLERANT SPECIES

- SILVICULTURAL OPTIONS TO CAPITALIZE ON THESE TRENDS EXIST

EMERGING CONCLUSIONS *continued*:

- DEER BROWSING AND FROST CAN OVERRIDE THE IMPORTANCE OF COMPETITION AND LEAD TO REGENERATION FAILURES, *EVEN ON DRY-MESIC (INTERMEDIATE) SITES*

- MODELS OF OAK STAND DYNAMICS AND DEVELOPMENT FOR USE IN REGIONS SIMILAR TO THE STUDY AREA SHOULD INCLUDE EFFECTS OF DEER BROWSING AND OTHER DISTURBANCES TO PRODUCE REALISTIC PREDICTIONS

- FACILITATION IS A POSSIBLE INTERACTION BETWEEN OAK AND OTHER PLANT SPECIES IN ADDITION TO COMPETITION

EMERGING CONCLUSIONS *continued*:

- PRESCRIBED BURNING INTERACTED WITH STAND TYPE AND OVERSTORY COVER - CAGED OAK SPROUTS TENDED TO REGAIN A GREATER PERCENTAGE OF PRE-BURN HEIGHT IN PLOTS WITH LOW AMOUNTS OF OVERSTORY COVER

- PRESCRIBED BURNING CAN BE DETRIMENTAL IN REGIONS WITH OVERABUNDANT DEER - DECREASED STATURE OF OAK SPROUTS REOPENS THE WINDOW OF SIGNIFICANT SUSCEPTIBILITY TO BROWSING AND FROST DAMAGE

EMERGING CONCLUSIONS *continued*:

- ONE PRESCRIBED BURN HAD ONLY SLIGHT EFFECTS ON LONG-TERM PATTERNS IN THE DISTRIBUTION AND COMPETITIVE POSITION OF RED MAPLE AND OAK

- A SECOND PRESCRIBED BURN FURTHER REDUCED THE STATURE OF RED MAPLE IN THE OAK STANDS, AND PERHAPS ITS ABUNDANCE - ANALYSES OF THE 2009 DATA ARE CURRENTLY UNDER WAY

EMERGING CONCLUSIONS *continued*:

- THE PERIOD WHEN OAK SAPLINGS ARE NEAR THE GROUND MUST BE MINIMIZED IN ORDER FOR THEM TO SUCCESSFULLY ESCAPE UNDERSTORY BROWSING AND FROST DAMAGE

- ARTIFICIAL REGENERATION WITH LARGE, HIGH-QUALITY OAK SEEDLINGS CAN INCREASE THE PERCENTAGE OF OAK STEMS RECRUITING INTO THE MIDDLESTORY AND OVERSTORY, BUT CAN BE AN EXPENSIVE OPTION

- REDUCTIONS IN DEER POPULATIONS WOULD ALLOW MORE FREQUENT SUCCESS WITH NATURAL REGENERATION

EMERGING CONCLUSIONS *continued*:

- **COMPLETE REMOVAL OF OVERSTORY AND UNDERSTORY COMPETITORS OF OAK CAN LEAD TO SIGNIFICANT NEW PROBLEMS SUCH AS BROWSING AND FROST DAMAGE THAT INCREASE MORTALITY**

- **SHELTERWOODS AND OTHER METHODS INVOLVING PARTIAL REMOVAL OF COMPETITORS CAN HELP BALANCE EFFECTS OF DETRIMENTAL FACTORS THAT CHANGE ACROSS GRADIENTS IN OVERSTORY AND UNDERSTORY STRUCTURE - *BUT*, DEER BROWSING MAY STILL RESULT IN REGENERATION FAILURES**

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